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ON THE ILLUMINATION OF MARITIME COASTS.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 19, 1886.*]

The beginnings of the illumination of maritime coasts are lost in the dim mists of antiquity. Nearly 3,000 years ago, the following lines were composed by the father of poetry:

. . . . and then he took the shield,
Massive and broad, whose brightness streamed as far
As the moon's rays. And as at sea the light
Of beacon, blazing in some lonely spot
By night, upon a mountain summit, shines
To mariners, whom the tempest's force has driven
Far from their friends across the fishy deep,
So from that glorious buckler of the son
Of Peleus, nobly wrought, a radiance streamed
Into the sky. . . . .

(*Bryant's translation of the Iliad*, xix, 450–459.)

The description of the blaze of a beacon light in these verses is too definite to admit of the slightest doubt of the existence of such aids to navigation, even at this remote period.

About 300 B. C., the celebrated "Colossus of Rhodes," an immense bronze statue, spanning with its legs the harbor entrance, was constructed, and is supposed to have served as a light-house, until it was destroyed by an earthquake, eighty years later. About the same time, the equally far-famed "Pharos of Alexandria" was built by Sostratos of Cnidus. It is said that the fire, burning on the top of it, was visible at a distance of more than thirty miles, according to which the tower must have been above 500 feet in height. Pliny informs us that the cost of the structure amounted to a sum equal to about $2,000,000, and considering the much greater value of money at that early period, there can be no doubt that the dimensions of the building must have been exceedingly great. From the Pharos of Alexandria, in ancient times, the name was derived for the entire family of light-houses, which terminology has been handed down to the present day by the French language —the French word for light-house being "*phare*." Other less celebrated light-houses are mentioned by old writers as having existed at Ostia, at Ravenna, at Capio, and at various points on the British and French coasts.

The *object* of all *ancient* lights was simply to mark the entrances to harbors or rivers important for navigation, while the intermediate stretches of the coast were not lit up. The *modern* objects of the illumination of maritime coasts are more comprehensive: not only are the entrances of important rivers and harbors marked, but the entire line of the coast is lit up by a continuous chain of lights of different appearance, in order to enable the mariner approaching the coast at night to determine his whereabouts, and to shape his course towards his destination. The lights destined to give first warning of the vicinity of the coastline, are the so-called "land fall-lights," or "primary coast-lights," lights of the most powerful degree of intensity, and placed at a very high elevation, so that their range of visibility is great, generally varying from about twenty to about twenty-five miles. The distance between two adjacent land fall-lights should always be smaller than the sum of the two ranges of visibility, so that in clear weather one of them must be sighted before the ship can get into danger. Their location should be on projecting points of the shore, so that the polygon formed by them encloses within its area as far as possible all outlying dangers to navigation.

Between the land fall-lights (or primary coast-lights, as they are termed in the United States,) are inserted secondary lights, for the purpose of filling gaps between them, that are too wide; again, for marking the entrances of rivers and harbors, and finally, for marking such outlying dangers to navigation as are not enclosed in the polygon formed by the land fall-lights. For this latter purpose, light-ships are frequently employed, the construction of towers on seaward points being always a difficult and costly undertaking.

Such are, in general outlines, the ruling modern principles of the illumination of maritime coasts, as they were laid down in a report to the French Commission of Lights, made by Admiral Rossel, in the year 1825. According to these principles, the light-house systems of the important maritime nations have been developed during the course of the present century to a most remarkable degree. At the commencement of it, the coasts of England, Ireland and Scotland were lit up by only forty lights, which number, eighty years later, had increased more than ten-fold—to about 460. Still more wonderful is the growth of the light-house system of the United States, which, from twenty-three lights in the year 1800, has advanced to about 650 in the year 1886.

In order to enable the mariner approaching the coast at night to determine his whereabouts on sighting the first light, each light must be furnished with a characteristic feature, by means of which it is recognized, by means of which its identity is established. Without, for the present, entering on the details of this subject, it may be mentioned that these various characteristic features, by means of which lights are distinguished from each other, are produced in three different ways, viz.:

(1.) By grouping; that is, by building two lights in close proximity to each other, far enough apart that at any distance they will appear separated; and sufficiently close, that they will always be recognized as belonging to each other.

(2.) By means of colors (red, blue and green light).

(3.) By means of giving the light a varying intensity, in such a way, that within a certain period of time it decreases from greatest brilliancy to entire darkness, and then again increases to greatest brilliancy.

This latter method is the one most frequently employed and it

is clear that the duration of the period within which the intensity of the light varies, affords an easy means of forming any number of different characteristics. We shall further on return to this subject, and then see in which way lights of varying intensity are produced.

This matter of "characterizing" lights is of the utmost importance—of an importance which may be said to increase in the same ratio as the number of lights marking the various maritime coasts increases. With the growing number of lights, the average distance between two adjacent ones is diminished, the danger of mistaking one of them for the other is correspondingly increased, and it is scarcely necessary to mention by what disastrous consequences to human life and property a mistake of that kind may, and very often has been, attended.

It is not required for the purposes above mentioned, that each light should possess a characteristic peculiarity exclusively its own, a characteristic which it shares with no other light, but it is merely necessary that one and the same characteristic should not repeat itself within too short a distance. How far two lights of the same characteristic should, at least, be distant from each other, in order to avoid the possibility of one of them being mistaken for the other, is a question which, according to local circumstances, may be decided differently. As a general rule, this question will resolve itself into the other one, of how far the mariner's reckoning under ordinary circumstances is apt to be astray; and again, as a general rule, it may be said that two lights of the same characteristic, that are eighty miles distant from each other, cannot be mistaken one for the other.

To return now to the example of a ship approaching the shore at night. Let us assume that at a distance of twenty miles from the shore the first land fall-light has been sighted and recognized by its characteristic; then the mariner can approximately determine his whereabouts, and accordingly shape his course to his destination say for instance towards the mouth of a river. In passing along the shore, he will successively sight other coast lights, the recognition of which will corroborate the correctness of his course. At a distance of say ten miles he will sight the lights marking the entrance of the river, and the course of the vessel will now be shaped according to these. When the entrance is passed, the channel, which now becomes narrow, is marked by "range lights." A

range consists of two lights built at some distance from each other, and located so that the straight line connecting the two indicates the direction of the channel, and in passing from one of these ranges into the other the ship can proceed up the river by night with the same safety as in day-time.*

Having given in the above the general outlines of the object of the illumination of maritime coasts, we now proceed to discuss the optical devices and appliances employed for it.

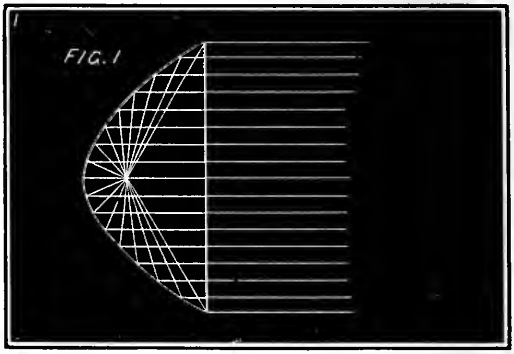
The ancient methods of light-house illumination are not known to us; there is, however, some reason to believe that in this respect, as in so many others, the ancients possessed knowledge and skill which were lost in the tremendous struggles preceding and following the downfall of Rome, and in the deep darkness which then for centuries settled over the nations of Europe.

Without entering into historical speculation on this subject, we will pass to the beginnings of the modern methods of light-house illumination. The first modern light-house of importance was the "Tour de Corduan" in the mouth of the Garonne, a French river emptying into the Bay of Biscay. This tower still exists and is perhaps the most magnificent structure of its kind on the face of the globe. It was finished in the year 1610, and for a long time was illuminated by burning billets of oak-wood in a *chauffer* on the top of the tower, later on by means of a coal-fire, but not until the year 1780 by means of lamps. The celebrated tower of Eddystone on the coast of Cornwall, until the beginning of this century, was lit up by means of twenty-four ordinary candles, unaided by any optical apparatus, and the tower on the Isle of May, also on the coast of Scotland, was illuminated by means of a coal-fire until the year 1816.

We perceive, from these examples, that the employment of the most primitive methods of light-house illumination reaches down to the very threshold of the present day, and, in considering these methods and their value, we find, above all, that they are extremely uneconomical. The rays of light emanating from a luminous point are distributed equally in all directions, and we may, therefore, properly speak of a globe of light being created by a lumi-

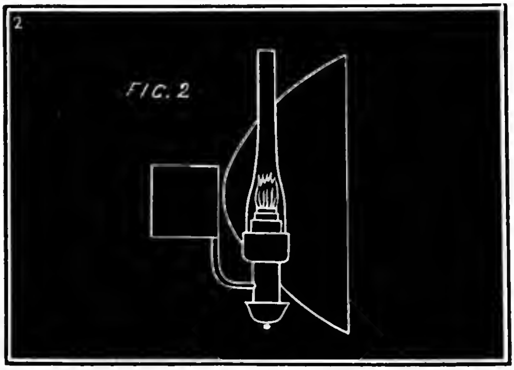
* The Delaware River from the Capes up to Philadelphia affords a remarkable example of a thorough and complete system of illumination as here described. E. A. G.

nous point. In our case, only a small part of the globe of light, created by the fire or the candles on the top of the tower, is actually utilized, namely, only that disc comprising the rays which lie immediately below the horizontal plane. Only these can reach the eye of the mariner, all others are useless; those above the horizontal plane being lost in space, and most of those below the horizontal plane striking the surface of the sea at points in the immediate surroundings of the tower, closer to it than a ship ever comes. In comparison to the entire amount of light produced, therefore, the amount of light actually utilized is very small. Hence, the intensity of the light in the useful direction is comparatively weak, and its range of visibility correspondingly small.

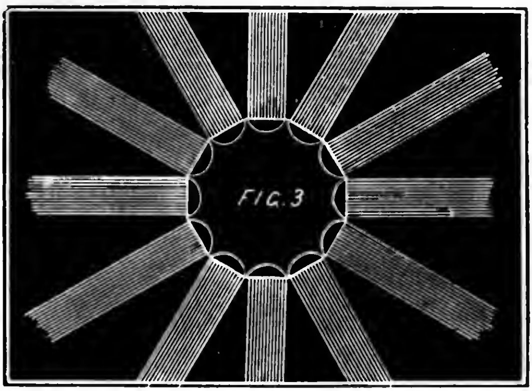


These considerations point directly to the requirements of an optical apparatus suitable for light-house purposes. Such an apparatus should be constructed so as to divert into the useful direction as many as possible of those rays, which without it would be lost. The greater the number of rays so diverted, the stronger will be the intensity of the light in the useful direction, and the greater, therefore, its range of visibility. A beginning in this respect was made on the "Tour de Corduan," mentioned before, by suspending an inverted cone over and into the fire burning on the top of the tower, in order to prevent the loss of light which escaped upwards. Later on, when candles and lamps commenced to be substituted for coal or wood fires, plane mirrors were placed behind them. From the plane mirrors, progress was made to spherical mirrors, and from these to parabolic reflectors. The

parabolic mirror possesses the property of reflecting in a bundle of parallel rays, the rays emanating from a luminous point situated in its focus, as shown in *Fig. 1*. Reflectors of this kind would, therefore, be eminently adapted for use on the aforementioned range



lights, the light of which need only be seen in one direction; that is, the direction of the channel. For this purpose, parabolic reflectors are still in use, and the arrangement of lamp and reflector is made as shown in *Fig. 2*; the flame of the lamp being situated



in the focus, the cylinder passing through an opening in the upper part of the reflector, and the oil-reservoir being situated behind it. In order to utilize the parabolic reflector for lights, which were required to be seen around the entire horizon, a number of them were arranged in a circle. Theoretically, each of these reflectors

would shed into space a bundle of parallel rays, and between these pencils of light there would remain dark angles, as shown in *Fig. 3*.

If this were the case in reality, then the object of illuminating the entire horizon would not have been attained, since, from a ship moving in one of the dark angles, the light would not be seen at all. In practice, however, the matter stands somewhat different; only the rays emanating from a luminous *point*, situated in the focus of the parabolic reflector, are reflected in a bundle of parallel rays. The flame of a lamp, however, is no luminous point; it has some extent, and those parts of it situated outside of the focus of the parabolic reflector will cause a divergency of the reflected rays, and, as far as this divergency occurs in the vicinity of the horizontal plane, it will serve to fill up the angles which otherwise would remain dark. An arrangement similar to the one shown in *Fig. 3* is still in use on light-ships. The parabolic reflectors are arranged in a circle, and enclosed by a circular lantern, through the centre of which the mast of the light-ship passes.

Although the angles between the bundles of rays are, as we have seen, filled with light, yet this light is, for obvious reasons, considerably weaker in intensity than the light in the bundles themselves. The illumination of the entire horizon, although complete, is, therefore, not a uniform one. In order to make it uniform, several tiers of parabolic reflectors were arranged one above the other, in such a way that the reflectors of an upper tier would stand over the gap between two reflectors of the next tier below. In this way, an almost entirely uniform illumination of the horizon was obtained, by a method, however, involving a great cost of maintenance, on account of the many lamps required.

In order to reduce this cost of maintenance, a smaller number of reflectors were arranged on a revolving triangular or square frame. Each side of this frame would shed into space a bundle of rays, and between these various bundles there would remain dark angles. On revolving the frame by means of a powerful clockwork, each point of the horizon, therefore, would be swept in regular periods alternately by light and by darkness. If, for instance, the frame were a square one making one entire revolution in four minutes, then the period of the light would be one minute; and from a ship approaching it, it would, in this space of

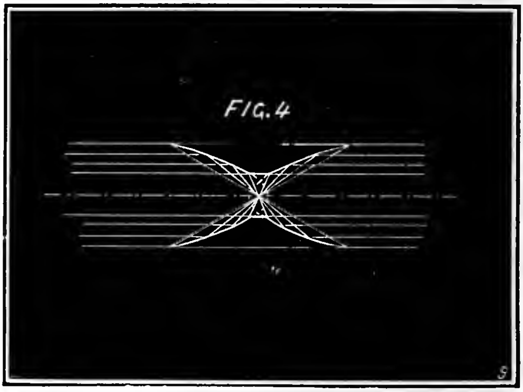
time, be seen decreasing from greatest brilliancy to entire darkness, and then increasing again to greatest brilliancy. Here, therefore, we have a method of producing the aforementioned lights of varying intensity, a method, however, which, has long since been supplanted by another one, that will be described later on. As a matter of general interest, it may be mentioned that a revolving light of this kind would be invisible at a distance of a few miles, were it not for the divergency of the rays caused by the extent of the flame. In explanation of this, let us suppose that there was no divergency of the rays; then each side of the revolving frame would shed into space a bundle of perfectly parallel rays, and the width of this bundle would be the same, at any distance from the light-house, as in the immediate vicinity of it, viz., only a few feet, or the width of the frame. At a distance of, say, ten miles from the light-house, this narrow streak of light would sweep by the eye of the observer with such an enormous rapidity that it would leave no impression on it; that is, the human eye would not be able to perceive it. In reality, however, we have, in the place of the bundle of parallel rays, a cone of light, on account of the divergency of the rays, and the width of this cone increases with the distance from the light-house. At a distance of ten miles, it is so wide that, notwithstanding the rapidity of its motion, it takes an appreciable time before it has passed the eye of the observer, a time amply sufficient for him to perceive it.

The desire to still further simplify the reflecting apparatus for light-houses has led to a very ingenious form of the parabolic reflector, by means of which the entire horizon is illuminated by a single lamp and a single reflector. The shape of this reflector is identical with the solid obtained by revolving a parabola around its parameter; that is, the straight line standing at right angles to its axis and passing through its focus. In *Fig. 4*, a central section of this reflector is given, which section appears in the form of two parabolas having one focus in common between them.

In this focus the flame of the lamp is placed, and it is clear that the rays in each central section must be reflected as shown; that is, they are uniformly reflected around the entire horizon.

Although the parabolic reflector certainly marks a very important progress in light-house illumination, yet it is subject to

serious defects. In the first place, a great amount of light is lost through absorption on the surface of the mirrors, even the best polished ones; again, a further considerable amount of light is lost through the divergency of the rays caused by the extent of the flame. As far as this divergency takes place in the horizontal plane, we have seen before that it is beneficial; as far, however, as it takes place outside of the horizontal plane, above it or below it, it simply means so much loss of light. Finally, the reflecting apparatus is objectionable on account of the great cost of maintenance involved. Only the apparatus shown in *Fig. 4*, the so-called "sideral light," is free from this defect, but it is applicable only for small lights.



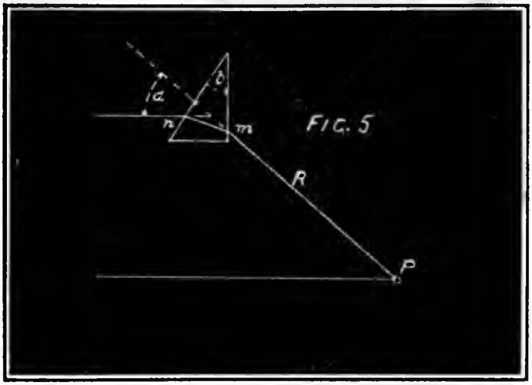
These various shortcomings have been materially diminished by the introduction of the "dioptric" or "refracting" apparatus in the place of the "catoptric" or "reflecting" apparatus. The dioptric apparatus was invented by the Frenchman, Augustin Fresnel, about the year 1820, and its theory is founded on the well-known laws of refraction.

A ray of light, when it passes obliquely from one medium into another one, experiences a change of direction which is called "refraction." On passing from a rarer medium, into a denser medium, for instance air into water, the ray is bent *towards* a line perpendicular to the surface; vice-versa, on passing from a denser medium into a rarer one, the ray is bent *away* from a line perpendicular to the surface.

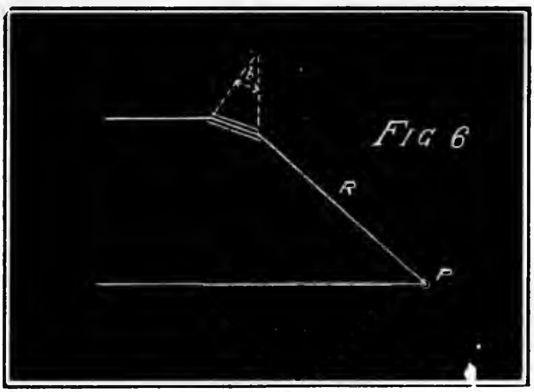
Now, let the line R, in *Fig. 5*, represent a ray emanating from

the luminous point P, and let a glass prism, the cross-section of which is a right-angled triangle, be interposed in the path of this ray, as shown in the sketch.

Then, on entering the prism (which is the denser medium) at m, the ray is bent *towards* the perpendicular, and on leaving the prism

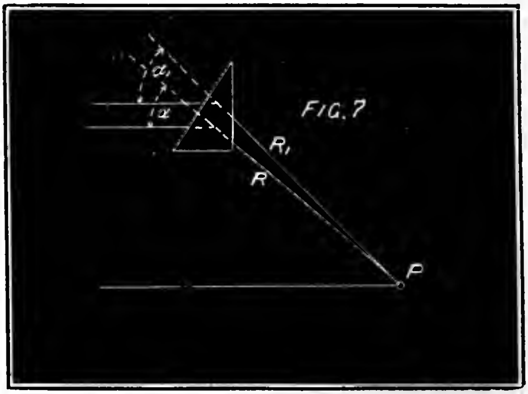


and re-entering the rarer medium, the air, at n, it will be refracted a second time, this time being bent away from the perpendicular. The sum of the two refractions, the angle a, is the entire change of direction experienced by the ray during its passage through the

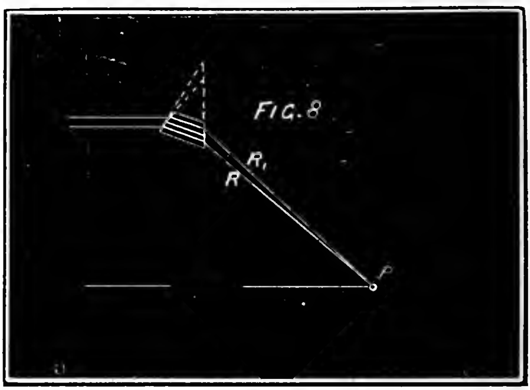


prism. Other circumstances being equal, the size of this angle a is dependent on the size of the angle b, which is called the refracting angle of the prism; the greater the angle b, the greater will be the angle a; the smaller b, the smaller will be a. Within certain limits, therefore, we have it in our hands, by a proper choice

of the size of the angle b, to direct the ray in any direction we please, and we can, for instance, direct it into the horizontal plane, as shown in the sketch. In order to divert this single ray into the horizontal plane, the entire prism is not required, but merely that



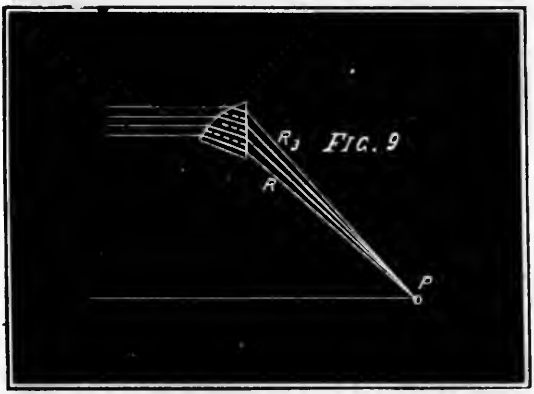
portion of it through which the ray actually passes, and which is shown in *Fig. 6.* If this "element of a prism" fulfils the condition of its refracting angle, b being of the requisite size, then the ray will be refracted by it, into the horizontal plane. Another ray, R_1



emanating from the same luminous point, but striking the prism somewhat above the first ray, R, as shown in *Fig. 7*, will require a greater change of direction in order to be diverted into the horizontal plane, because evidently the angle a_1 is greater than the angle a.

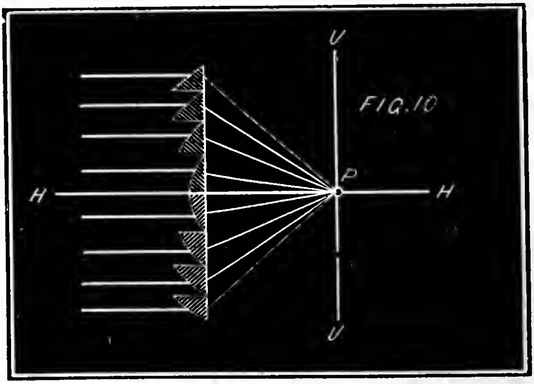
The required greater change of direction can be brought about, as we have seen, by a greater refracting angle, and we can, therefore, divert this second ray into the horizontal plane, by placing on the top of our first "element of a prism" a second one, with a somewhat larger refracting angle, as shown in *Fig. 8*.

In a similar manner we can refract into the horizontal plane a third and a fourth ray by simply placing on the top of our two elements of prisms a third and a fourth one with still larger refracting angles (see *Fig. 9*), and we perceive that by doing this the originally straight line of the hypothenuse of our cross-section is changed into a polygon of as many sides as there are rays diverted into the horizontal plane.

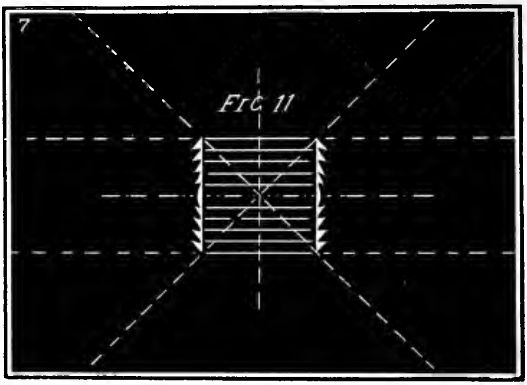


In the sketch, four rays emanating from the luminous point P, are thus divided; we can, however, with the same facility, divert fifty, or 100 or 1,000 by simply making our elements of prisms thinner; or, in other words, by making the sides of our polygon more numerous and correspondingly smaller in length, and inasmuch as a single ray requires for its passage an element of prism of an inappreciable thickness only, we can divert *all* the rays that strike the rear side of the prism by making our elements of prisms inappreciably thick or; in other words, by making the sides of our polygon infinitely *small* in length and infinitely *great* in number, by which process the polygon is transformed into a continuous curve. The precise form of this curve can be computed, and when this is done and the glass is ground accurately according to it, then all the rays emanating from P and striking the rear side of the prism,

will be diverted into the horizontal plane. Below the first prism (see *Fig. 10*) we can, according to the same principles, arrange a second one, which will divert into the horizontal plane all the rays coming from *P* and striking *its* rear side; below this second one, a third one, and so on, down to the horizontal plane passing through



the point *P*. Below this horizontal plane, a similar series of prisms can be arranged, with this difference, that they will stand upside down, the refraction here having to take place the other way. In this manner, we obtain a cross-section (see *Fig. 10*) which has the

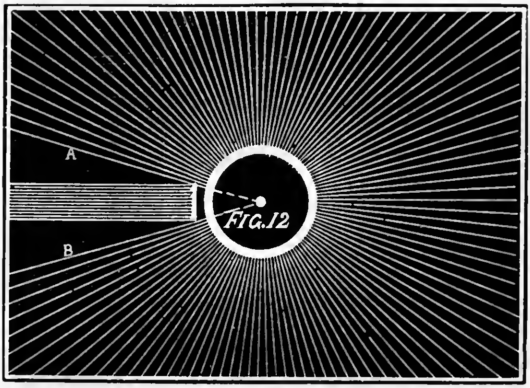


property of diverting into the horizontal plane by refraction, all the rays coming from a luminous point situated in its focus *P*.

This is the fundamental cross-section of Fresnel's apparatus, and from it we develop, by means of a few simple operations, the three main forms of it. The first of these operations consists in

revolving the fundamental cross-section around the vertical line *V V*, passing through its focus. The solid obtained in this way has the shape of a cylinder, composed of prismatic rings, put one on the top of the other. It is called the lenticular drum, and a vertical central section of it is shown in *Fig. 11*.

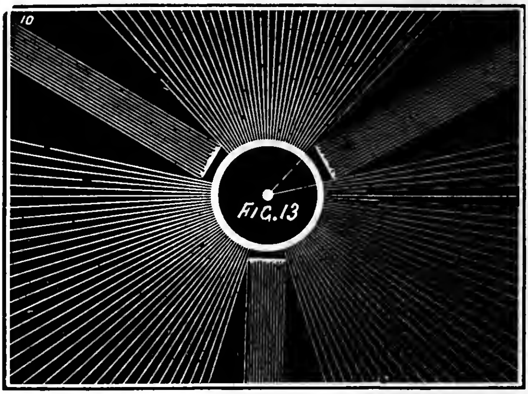
From what we know of the properties of the fundamental cross-section, it is clear that the lenticular drum must refract into the horizontal plane, all rays emanating from a flame situated in its focus and striking the interior smooth side of the drum. This refraction taking place uniformly all around, the entire horizon is thereby uniformly illuminated by what is termed a fixed light.



The second main form of Fresnel's apparatus is obtained by moving the fundamental cross-section in a horizontal position vertically upwards; the resulting solid consists of a number of prisms standing upright and side by side, the horizontal cross-section of this system of prisms being identical with the fundamental cross-section. If a system of prisms of this kind be placed in front of the lenticular drum, then the result clearly must be, that the rays leaving the drum radially and striking the rear smooth side of this appliance, are by it refracted into a bundle of parallel rays, as shown in *Fig. 12*.

The light which, without the system of prisms, would have covered the entire angle *A B*, is now condensed into the narrow space of the bundle, shown in the sketch. The light of the bundle will therefore be of greater intensity than the rest of the light, which the lenticular drum sheds radially around the horizon, and

at each side of the bundle there will be dark angles. If now the system of prisms be placed on a frame revolving around the fixed lenticular drum, then each point of the horizon will be successively swept by an intense flash of light preceded and followed by a short darkness; and the mariner approaching this light from afar will see during the greater part of the time the fixed light of the lenticular drum, varied at regular intervals by an intense flash preceded and followed by a short darkness. This second form of Fresnel's apparatus is termed the fixed light varied by flashes. Generally, there are several systems of prisms mounted on the revolving frame; for instance, three, as in *Fig. 13*.



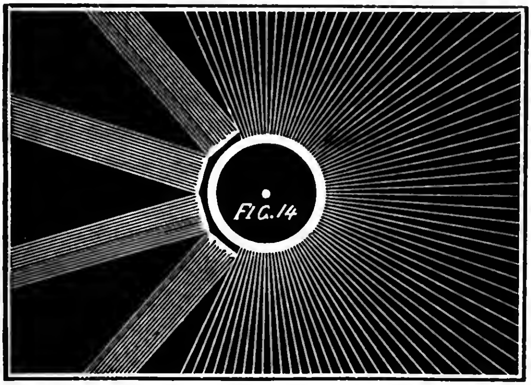
If the frame, in this case, were to make one entire revolution in three minutes, then the mariner approaching the light would see a flash every minute preceded and followed by a short darkness, and between each two flashes, he would see the fixed light of the lenticular drum.

It is not uncommon to arrange all the flashes close to each other on one side of the revolving frame, as shown in *Fig. 14*.

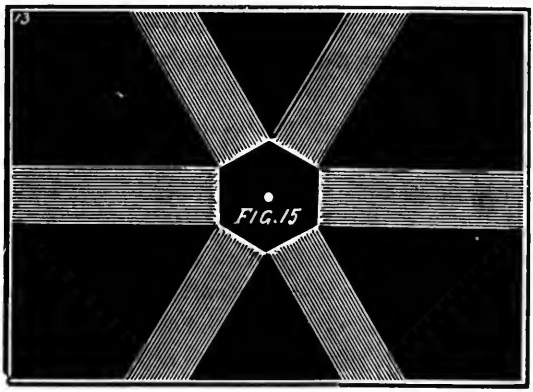
Here the mariner will see, during a part of the time, the fixed light of the lenticular drum, and then four consecutive flashes, separated from each other by short darkness. The arrangement of the fixed light varied by flashes can be further diversified by introducing colors; for instance, by making the flashes alternately red and white.

The third form of Fresnel's apparatus is developed by revolving

the fundamental cross-section around the line *H, H* (see *Fig. 10*), as an axis. The solid obtained in this way is a round disc, consisting of concentric prismatic rings, any central section of which must be identical with the fundamental section. It is evident, therefore, that this disc must refract in a bundle of parallel rays,



all rays coming from a luminous point, situated in its focus and striking the smooth rear side of the disc. This appliance, therefore, performs, by means of refraction, precisely what the parabolic mirror performs by means of reflection. In order to



utilize it for light-house purposes, the disc is trimmed into the shape of a rectangular panel and a number of these panels are then combined to form an optical apparatus, polygonal in form, each side of which will shed into space a bundle of parallel rays. In *Fig. 15*, the plan of a hexagonal apparatus of this kind is shown.

From each panel a bundle of rays emanates, and between the various bundles there remain dark angles. If, now, the entire apparatus be revolved by means of a clock-work, then each point of the horizon will be alternately swept by light and by darkness, and the mariner approaching the light will see it in this manner: he will perceive it within a certain period of time gradually decrease from greatest brilliancy to entire darkness, and then again increase to greatest brilliancy. If, for instance, the hexagonal apparatus shown in *Fig. 15* were to make one entire revolution in three minutes, then the changes in the intensity of the light described above would take place in the space of half a minute. This third main form of Fresnel's apparatus is called the flashing light.

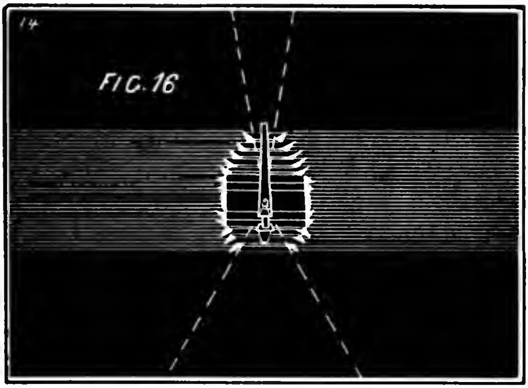
The three main forms of Fresnel's apparatus described above, the fixed light, the fixed light varied by flashes, and the flashing light, afford the possibility of producing an almost unlimited number of different characteristics. In the illumination of the coasts of the United States the three main forms are diversified as follows:

(1.) Fixed white light;
(2.) Fixed red light;
(3.) Flashing white light;
(4.) Flashing red light;
(5.) Flashing white and red light;
(6.) Fixed white light varied by white flashes;
(7.) Fixed white light varied by red flashes;
(8.) Fixed white light varied by red and white flashes.
(9.) Fixed red light varied by red flashes.

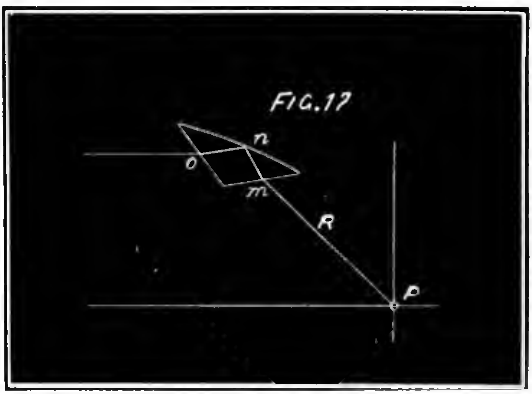
It is hardly necessary to add that these nine forms are further diversified by making the periods of time, within which the intensity varies, of different lengths.

An inspection of *Fig. 11* will show that, although the lenticular drum refracts into the horizontal plane, a great many rays, which without it would be lost, yet it by no means so refracts *all* the rays that are produced. A very considerable portion is still lost, partially by escaping above, partially by escaping below. A simple remedy would seem to suggest itself by heightening the lenticular drum; it would appear that the higher it is made, the fewer rays can escape above and below. But there is a limit to the application of this remedy; with the increasing height of the apparatus, the upper and lower rays will strike the smooth inside of it more and more

obliquely, thereby more and more increasing the loss of light by reflection to the inside of the drum. Practical experience has taught that the angle subtended by the height of the apparatus at its focus should not exceed 70°, and this therefore marks the limit to which the height of the lenticular drum can be profitably car-



ried. Fresnel himself has supplied a remedy for the above mentioned defect, which meets all demands. Above and below the lenticular drum, he arranged a series of prismatic rings which divert into the horizontal plane the rays striking them, not by refraction only, but by a combination of refraction and reflection.



A complete lenticular apparatus, furnished with this addition, is shown in *Fig. 16.* In the middle will be recognized the lenticular drum, while above it there are five, and below it there are three, of the above-described prismatic rings, the so-called "catadioptric rings," the operation of which is explained by *Fig. 17.*

The sketch shows, on an enlarged scale, the cross-section of one of the upper catadioptric rings. The ray enters at *m*, and is then refracted for the first time; it then strikes at *n* so obliquely, that it is totally reflected, and in leaving the prism at *o*, it is refracted a second time. The shape of the cross-section is carefully adjusted so that the two refractions and the one reflection will result in diverting the ray into the horizontal plane.

It is evident that from the apparatus, improved as shown in *Fig. 16*, only a small amount of light can escape without being turned to use, and Fresnel, therefore, through the addition of the catadioptric rings had raised his invention to a state of perfection, which it has been impossible to further improve upon.

The apparatus is employed in different sizes; for a small light it is only a few feet high; while for a first order coast light, with its flame of nearly five inches in diameter, it has a height of eight or nine feet and a maximum diameter of about six feet.

In the United States, the light is produced almost exclusively by mineral-oil lamps with argand burners. For powerful lights, several concentric wicks (as many as five) are used, with air spaces between them, the light produced by the inner wicks thus shining through the outer flames, by which expedient the intensity of the light is of course increased. For the larger lamps, ingenious contrivances have been constructed in order to secure the conveyance of a sufficient and constantly uniform supply of oil to the flame.

The range of visibility of lights is dependent on two circumstances, viz., their height above the sea and their intensity. We therefore speak of a geographical and of a luminous range. If the earth were not surrounded by an atmosphere, then the geographical range would be determined by the tangent drawn from the light to the circumference of our globe. The rays on their passage to the surface of the earth, however, successively enter denser and denser strata of air, and consequently experience a continuous refraction, as a result of which the path of the light changes from a straight line into a curve, the convexity of which is turned upwards. The geographical range is thus increased by the refractive action of the atmosphere. In connection with this, it should be mentioned that the light leaving the apparatus, in order to reach the eye of the mariner must be directed, not as we have hitherto assumed, into the horizontal plane, but slightly below it. The rays

emanating from the lenticular drum are therefore depressed by simply raising the most luminous portion of the flame somewhat above the focus, while the rays coming from the catadioptric rings are depressed by giving these latter a corresponding inclination.

The greatest range in our immediate vicinity is found at the lights on Navesink Heights; they are elevated 248 feet above the sea, and in clear weather are visible about twenty-two nautical miles. The lights of Absecon and Cape May are elevated 167 feet and are visible about nineteen miles. On the Pacific slope, much higher elevations are found; the light of Cape Mendocino, Cal., for instance is elevated 423 feet, and is visible twenty-eight miles. One of the highest light-house elevations in the world is that of a light at the Cape of Good Hope, which is 810 feet above the level of the sea, and can be seen at a distance of thirty-six miles.

A DEDUCTION FROM THE PRINCIPLE "THE MOMENT OF THE MOMENTUM" IN THE CASE OF TURBINES.

BY PROFESSOR DE VOLSON WOOD.

Some time since I made the following transformation of the "moment of momentum," to see if it would shed any light upon the action of the water in a turbine. This principle being subject to independent proof, any deduction from it will be valid.

In the case of turbines, the moment of momentum of the water flowing through the wheel into the angular velocity of the wheel equals the rate of doing work; that is,

$$\frac{du}{dt} = M V \rho \omega \Big]_{\text{initial limit.}}^{\text{variable limit.}} \qquad (1)$$

in which

M = the mass of water flowing through the wheel in a unit of time;

V = the circumferential velocity of the water;

ρ = the radius-vector from the centre of the wheel to any point in the buckets;

ω = the constant angular velocity of the wheel;

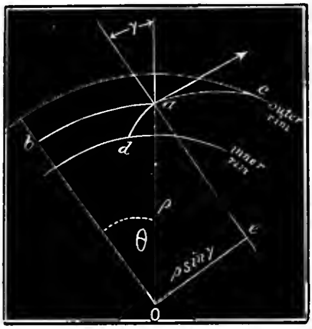
t = the time considered;

u = the work done in the time t.

Since the work is done at a uniform rate, it is only necessary to consider the work done in a unit of time, and that unit may be one second, hence integrating, and making $t = 1$, we have

$$u = \omega \Big[M V \rho \Big]_{\text{initial lim.}}^{\text{gen. lim.}} \tag{2}$$

for the work done per second. The quantity within the parenthesis is the "moment of the momentum," and between the limits the expression becomes — the work done by the water from its entrance into the wheel to any point (or arc) in the wheel equals the angular velocity of the wheel into the difference of the moment of the momentum of the water at entrance and at a distance ρ in the wheel.



Let

δ = the density of a cubic foot of water $= 62\cdot5 \div 32\cdot2$;
Q = the cubic feet of water flowing past an arc $b\,a = \rho\,\theta$;
θ = the angular part of the wheel through which Q flows;
ρ = O a,
v_1 = the circumferential velocity, in reference to the earth, of the water passing $a\,b$;
v = the velocity of the water along the bucket at a, in reference to the bucket;
γ = the angle between a normal to the bucket at a, and the radius through a prolonged;

then

$$\begin{aligned} v_1 &= v \cos \gamma, \\ M &= \delta\, Q, \\ V &= v_1 - \omega \rho \\ &= v \cos \gamma - \omega \rho, \end{aligned}$$

where $\omega \rho$ is the circumferential velocity of the wheel along the arc $a b$; and equation (2) becomes

$$u = \delta \, Q \, \omega \left[(v \cos \gamma - \omega \rho) \rho \right]_{\text{initial lim.}}^{\text{gen. lim.}} \tag{3}$$

The moment of the momentum of the radial component of v will be zero, since the direction of its action will be through the centre of the wheel; hence the last expression is the total moment into the angular velocity.

Differentiating, observing that in the operation the inferior limits disappear, we have,

$$\frac{d u}{\omega} = \delta \, Q \left[- 2 \, \omega \, \rho \, d \, \rho + v \cos \gamma \, d \, \rho - \rho \, v \sin \gamma \, d \gamma + \rho \cos \gamma \, d \, v \right].$$

Let $x =$ the depth of the buckets at distance ρ from the centre;
$m = \delta \, x \, \rho \, d \, \theta \, d \, \rho =$ the mass of an elementary prism at a;
then

$$d \, Q = \delta \, x \, \rho \, . \, v \sin \gamma \, . \, \theta = \frac{m}{d \, \theta \, d \, \rho} \, . \, v \sin \gamma \, . \, \theta,$$

substituting which in the preceding, and differentiating again in reference to θ, gives us

$$\frac{d^2 \, u}{\omega} = \rho \sin \gamma \, . \, m \left(- 2 \, \omega \, v + \frac{v^2 \cos \gamma}{\rho} - v \sin \gamma \frac{d \, \gamma}{d \, \rho} + \cos \gamma \frac{d \, v}{d \, \rho} \right)$$

The $d^2 u$ is an element of the work, and an examination of the process by which it has been obtained shows, from the last differentiation, that it is the work of an elementary prism, whose mass is m, and from the first differentiation that it is the work produced by this mass on account of its change of position and direction of motion in reference to a change in the variables ρ, v and γ. In the last equation $\rho \sin \gamma$ is the perpendicular from the centre of the wheel, O, upon the normal to the bucket at a; and hence we infer that the quantities in the parenthesis multiplied by m are pressures normal to the bucket at a, due to the several changes in motion of the mass m with the wheel and along the bucket. Some of the terms in the parenthesis are readily interpreted, but the signification of others is not at once apparent, and although it may be a good exercise to determine their meaning from this standpoint, yet it is unnecessary to do so since it is virtually done in the solution of the problem of the turbine by Mr. Woodbridge, in the November number of this JOURNAL.

PRELIMINARY IDEAS ON THE CREMATION OF SEWER-GAS.

A METHOD FOR THE BETTER VENTILATION OF SEWERS, DRAINS, ETC.

BY N. WILEY THOMAS.

The term sewage is applied to all refuse and waste matter, which, if allowed to remain in or about our houses, in contact with air or without it, will produce disease and, in many cases, death.

The removal of this matter by methods originally intended to preclude any dangerous results was, and presumably is now, the office of a sewer system.

Sewer-gas is a comprehensive term, used to designate a greater or less number of gases and vapors, very complex in composition. This complexity of composition is not due to the great number of elements represented in the gas, but to the variety of ways in which these elements may combine with each other. The elements present in sewer-gas, and, indeed, certain of their compounds, are practically without any injurious effect. There are, however, products intermediate between these elementary bodies and the more ultimate products which are deleterious, and in the possibility of the formation of just these intermediate products lies the danger of sewer-gas. These are the results of the partial decomposition of the organic matter contained in sewage.

It is a well-known fact that all decomposition, as well as chemical combination, is greatly facilitated by heat. The absence of certain conditions is the real cause of the formation of the dangerous compounds. If sufficient oxygen with additional heat could be employed, these compounds, if formed at all, would exist only momentarily; they would immediately be converted into the more nearly ultimate or simple products. These latter are, indeed, obtained in every case, but the intermediate or dangerous products exist as such for a period of time sufficient to accomplish their deadly work. The methods now in use, we are convinced, do not succeed in accomplishing the object for which they have been proposed.

The problem of sanitary drainage has not as yet been solved. The sewer is, in the present state of civilization, a necessity; what remains to be done is to remove from it its dangerous nature. Sewer-gas, we believe, will be admitted to be the great dangerous product found in sewers. It is not our purpose to give a detailed account of different systems now in use, but simply, first, to remind the reader that the great majority of the so-called traps, about which the plumber and the builder make so many pretensions, are but a delusion and a snare. They might be more properly called death-traps. And, indeed, it must be said that the more complex they are the more dangerous do they become, since the readiness with which they get out of order increases with their complexity. In a word, then, the present methods are entirely superficial; they do not go to the root of the matter.

It is the purpose of this paper to briefly show how, by the cremation of sewer-gas, sewers may not only be ventilated, but, as a consequence, how this gas can also be destroyed:

The sewers, by means of suitable pipes, which should intercept near the roof, could be connected with a high chimney or stack; these pipes having passed through a furnace heated to redness before reaching the chimney, should then, by means of that chimney, be allowed to enter the atmosphere.

We believe it will be admitted that, at such a heat, the sewer-gas will be destroyed. Not only so, but this very heat with such draught would cause the current of gas to seek exit by means of this chimney. Should this draught be insufficient, blowers might be advantageously used to assist in the operation. By the destruction of the sewer-gas, we simply mean its conversion into simpler compounds, and we reaffirm our belief that at such temperature and in the presence of sufficient oxygen, this gas would be rendered harmless. The scheme is certainly theoretically possible; and in the hands of a competent engineer, could be made most effectual. Especially is it recommended to estates or large manufactories, where much can be done in this direction. The portion of the sewer used could be ventilated without assuming to ventilate the entire sewer. Another point; the boiler-furnace could be used to supply the heat. It is, at this time, merely intended to state the essential principles of the scheme. The main features are not original, but are based on the process of cremation

wherever carried out. The feasibility of the method could be tested without any considerable expense. Should it be found impracticable to place the pipes in the furnace, the connection could be made by simply allowing the gases of the sewer to mix with the gases of the furnace, and then associated with the latter to pass into the chimney. The advantages of the pneumatic system are more fully obtained than could be possibly hoped for without the presence of the heated gases. The scheme has the advantage of being extremely simple.

Any of our sewers now in use, whether those for surface drainage or those for the house and water-closet drainage could be so connected as to obtain the advantages of this system.

It is freely admitted that, at the present time, there is pressing need for the investigation of the question of sewage, and it is the principal intent of this paper to call attention to this subject, and to promote further investigation.

Girard College, November 3, 1886.

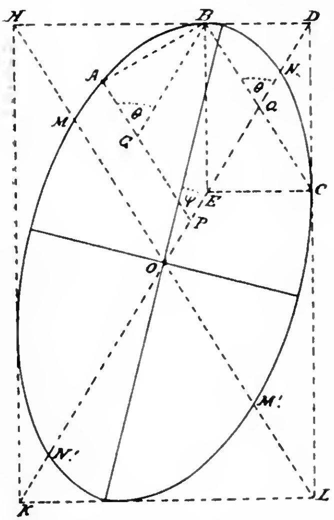
ATTRACTIVE FORCES IN GASES.—The founders of the kinetic theory in gases considered the gaseous molecules as solid, slightly deformable, elastic spheres, and this opinion is generally prevalent at the present day. Maxwell also considered the hypothesis that the molecules behave as centres of force, which repel one another in the inverse proportion of the fifth power of their distance. Boltzmann thinks it desirable to adopt various hypotheses, and especially to inquire whether a complete kinetic theory can be based upon attractive forces alone. He considers that the time integral can be employed with advantage so as to give a result, which will be both quantitatively and qualitatively in accordance with the laws of dissociation. The passage from dissociation to association differs from the condition of fluidity only in the circumstance that in the latter case aggregates are formed of many molecules which remain partly wavering as steam bubbles, partly adhering to the walls of the vessel or sinking through their weight to the bottom. The possibility of forming such aggregates through proper cooling may be readily deduced from the assumption of attracting molecular forces. The same forces which are active in the shocks of molecules, may also be applied to an explanation of dissociation and fluidity, whereas the hypothesis of repulsive forces during the approach of the gaseous molecules requires the assumption of entirely new forces for the explanation of those phenomena. As long as the collision of more than two molecules is absolutely prohibited, it can never be possible that two molecules can remain permanently together. Through the intervention of a third molecule, the living forces can be so diminished as to admit of a permanent union, and to introduce the various atomicities of molecules, the valency of atoms, etc.—*Annalen der Physik und Chemie, November 1, 1885.*

A NEWLY-DISCOVERED PROPERTY OF THE ELLIPSE.

BY L. D'AURIA.

In studying certain relations between physical quantities relatively to tidal rivers, the following problem of the ellipse occurred to the writer:

Given, of an ellipse, two tangents, $D\ B$, $D\ C$, at right angle with each other, the distances of their points of tangency, B, C, from their point of intersection D, and a third point A, determine the ellipse.



Being unable to find the solution of this problem in books of analytical geometry, the writer proceeded to solve it by the following method:

Let A, B, C . . . represent the desired ellipse, and upon the lines $B\ D$, $C\ D$ construct the rectangle $B\ D\ C\ E$. The diagonal $D\ E$ of such rectangle will determine the position of the transversal axis $N\ N'$ of the ellipse, and the other diagonal $B\ C$ will determine the inclination of the conjugate axis $M\ M'$, since $B\ C$ is bisected by $N\ N'$.

Now denote by (x_1, y_1) and (x_2, y_2) the co-ordinates of the points A and B, respectively; and by α, β the conjugate semi-axes $O\ N$, $O\ M$ of the ellipse. We have the following equations:

$$\alpha^2 y_1^2 + \beta^2 x_1^2 = \alpha^2 \beta^2; \quad \alpha^2 y_2^2 + \beta^2 x_2^2 = \alpha^2 \beta^2;$$

and can deduce

$$x_1^2 = x_2^2 - \frac{\alpha^2}{\beta^2}(y_1^2 - y_2^2). \tag{1}$$

Since the angular coefficients of the tangents $B D$, $C D$ are in the present case equal to *one*, because $B Q = Q C = Q D$; and since the analytical expression of such coefficient for the tangent $D B$ is

$$\frac{\beta^2 x_2}{\alpha^2 y_2},$$

we obtain the relation

$$\frac{\alpha^2}{\beta^2} = \frac{x_2}{y_2};$$

and substituting in equation (1), we have

$$x_1^2 = x_2^2 - \frac{x_2}{y_2}(y_1^2 - y_2^2). \tag{2}$$

Put $A B = l$; $A G = h$; $P Q = k$, will be

$$l^2 = h^2 + k(x_2 - x_1) - 2 h k \cos\theta;$$

which gives

$$x_1 = x_2 + \frac{h^2 - l^2 - 2 h k \cos\theta}{k}. \tag{3}$$

Put for brevity

$$\frac{h^2 - l^2 - 2 h k \cos\theta}{k} = -m;$$

will be

$$x_1^2 = x_2^2 - 2 m x_2 + m^2; \tag{4}$$

and comparing with equation (2), we have

$$2 m y_2 x_2 - m^2 y_2 = y_1^2 x_2 - x_2 y_2^2,$$

or

$$x_2 = \frac{m^2 y_2}{2 m y_2 + y_2^2 - y_1^2}, \tag{5}$$

which determines the centre O of the ellipse.

Solving the equations

$$\alpha^2 y_2^2 + \beta^2 x_2^2 = \alpha^2 \beta^2, \quad \frac{\alpha^2}{\beta^2} = \frac{x_2}{y_2},$$

for α^2 and β^2 will be found

$$\alpha^2 = x_2(x_2 + y_2); \tag{6}$$

$$\beta^2 = y_2(y_2 + x_2). \tag{7}$$

Since the value of x_2 is given by equation (5), the values of α and β can be determined by equations (6) and (7); so that denoting by a, b, the principal semi-axes of the ellipse, the well known equations

$$\left.\begin{aligned}(a+b)^2 &= \alpha^2 + \beta^2 + 2\,\alpha\,\beta\sin\theta\,; \\ (a-b)^2 &= \alpha^2 + \beta^2 - 2\,\alpha\,\beta\sin\theta\,;\end{aligned}\right\} \tag{8}$$

will afford the determination of a and b since the angle θ is known. In fact, solving equations (9) for a and b will be found

$$a = \tfrac{1}{2}\left\{\sqrt{\alpha^2 + \beta^2 + 2\,\alpha\,\beta\sin\theta} + \sqrt{\alpha^2 + \beta^2 - 2\,\alpha\,\beta\sin\theta}\right\}$$

$$b = \tfrac{1}{2}\left\{\sqrt{\alpha^2 + \beta^2 + 2\,\alpha\,\beta\sin\theta} - \sqrt{\alpha^2 + \beta^2 - 2\,\alpha\,\beta\sin\theta}\right\}$$

Now let ψ represent the angle formed by $O\,D$ with the principal semi-axes a of the ellipse, will be

$$\alpha^2 = \frac{a^2 b^2}{a^2 \sin^2\psi + b^2\cos^2\psi} = \frac{a^2 b^2}{\sin^2\psi\,(a^2 - b^2) + b^2},$$

hence

$$\sin\psi = \frac{b\sqrt{a^2 - \alpha^2}}{\alpha\sqrt{a^2 - b^2}}. \tag{9}$$

Having determined the position of the centre of the ellipse by equation (5), the angle ψ will enable to describe the ellipse upon its principal axes by the well-known methods given in books of analytical geometry.

In the solution of the above problem, the relations (6) and (7) appeared to the writer to be of some importance. After little examination it became apparent that by summing them up, the following remarkable relation would result, viz.:

$$\alpha^2 + \beta^2 = (x_2 + y_2)^2,$$

and observing that

$$x_2 = O\,Q,\ y_2 = Q\,B = Q\,D,\ x_2 + y_2 = O\,D,$$

it follows

$$\sqrt{\overline{O\,M}^2 + \overline{O\,N}^2} = O\,D \tag{10}$$

This expresses a new property of the ellipse, namely:

If on the continuation of one of the conjugate semi-axes of an

ellipse a point is taken whose distance from the centre is equal to the square root of the sum of the squares of such semi-axes, the tangents thrown to the ellipse from such point will be at right angle with each other.

THE FUTURE WATER-SUPPLY OF PHILADELPHIA.

[*Abstract of the Report of* RUDOLPH HERING, *Engineer in charge of Surveys for the Future Water-Supply of the City of Philadelphia.*]

The final report of Rudolph Hering, engineer in charge of surveys for the future water-supply of the city of Philadelphia, was lately presented to the Water Committee of the City Councils. This report closes the three years' investigations, by the city, of all the available sources for the future water-supply of Philadelphia. It is a very voluminous document, and embodies what is regarded by scientific engineers as the most complete of any similar known work. The survey cost the city the aggregate sum of $80,000. Nearly 100 persons were engaged in the survey and sanitary investigation of the water-shed from which Philadelphia's future supply must come. Accompanying the report is a large number of plates, charts, and tables, showing the population of the surveyed territory, the topography of the country, the rain-fall of the various districts within a radius of 150 miles of Philadelphia, the location of proposed reservoirs, and a variety of other valuable detail information on the subject. The Councils had deferred consideration of certain propositions and of the subject of the water supply in general, during the summer months, awaiting the completion of this survey, and, with the information contained in the report now before them, it is expected that the subject will be taken up, and decided at an early date.

THE REPORT.

Mr. Hering says that the office corps has been engaged in computing the stream-flows of the Perkiomen, Tohickon and Neshaminy Creeks, in ascertaining the available storage in each of the respective valleys, in estimating its cost, and in arranging and compiling the tables, maps, and charts for the final report, and then continues:

In approaching the solution of the question as to where the city should go for better water when the Schuylkill River is no longer a fit source of supply, the definite conclusions arrived at in the previous reports were substantially as follows:

Two sources present themselves as excellent and superior to all others, viz., certain tributaries of the Delaware and Lehigh Rivers in the Blue Mountains. While either of these two rivers, or both, must be made use of at some distant date, other sources are at hand which, at a much smaller outlay, will furnish water of satisfactory quality and quantity for some time.

It was found that the Delaware River above Trenton, the Tohickon Creek, and the upper Perkiomen Creek, with its branches above Frederick (excepting the Macoby Creek), would all furnish a supply to which, as far as the quality of water is concerned, no reasonable objections can be made. The selection of the best among these near sources, however, depends upon the quantity of water available from each, either directly or by storage, in order to supply the city daily with 200,000,000 gallons, and upon the comparative cost of securing this quantity.

The latter two questions were not fully answered in the last report. They have now been finally determined. The upper Perkiomen Creek and its branches cannot be relied upon to furnish more than 89,000,000 gallons per day during a year of minimum rain-fall. An increase over this quantity would have to be obtained from the Blue Mountains. The Tohickon Creek could not be depended upon ordinarily to furnish more than 90,000,000 gallons per day, and in minimum years not more than 80,000,000 gallons. An increase beyond this amount would have to obtained from the Delaware River at Point Pleasant.

It is interesting to note that the Tohickon Creek gives the greatest average yield of water per square mile, and the Perkiomen Creek, above Green Lane, the next greatest, while the northeast branch of the Perkiomen gives the least. The computed average, minimum, daily yield in million-gallons from the water-sheds of the Tohickon and Perkiomen at Green Lane is: Tohickon, 86·5; Perkiomen at Green Lane, 60·1. Had the progress of the investigation made it certain that only stored water from the Perkiomen and neighboring water-sheds could be used for a future supply, it would have been necessary to enter into the question of storage and available quantity more fully. As, however, the economy of procuring the Delaware water at Point Pleasant, and the superior quality of the water in the Tohickon water-shed as compared with the Neshaminy, and particularly of

the lower Perkiomen, became evident, it was not considered essential to spend the time that would have been necessary for the comparison outlined above. The deductions which have been made and the results reached therefrom, were considered sufficiently close under the circumstances.

Estimates of cost for supplying 210,000,000 gallons daily, which was the amount to be provided for, and which can be conveyed to the city by an aqueduct twelve feet in diameter, show that the project contemplating the furnishing of 90,000,000 gallons of Tohickon water by gravity, and of pumping 120,000,000 from the Delaware River by water-power—in other words, the "Point Pleasant scheme"—is decidedly the most economical, and it is therefore the project recommended to the city in this report. The Delaware River below Point Pleasant, having a minimum flow at this point of some 1,500,000,000 gallons, would not be damaged by the withdrawal of 200,000,000 gallons.

Aqueducts.—But little needs to be added on this subject. Descriptions of the available routes to the different points where the water could be obtained have already been given, and the best of them have been carefully surveyed, mapped, and studied by means of profiles and estimates of cost. The aqueducts were estimated as having a diameter of twelve feet and a grade of one in 6,000. In building the same, it will be advantageous, in many instances, to deviate from a circular form, and other slight changes from the preliminary plans will be advisable. As the object of the present investigation was the solution of the broad question as to the best source for the future supply and the probable cost, it was not considered necessary to enter upon details regarding the construction of the aqueducts, when the cost was not materially affected thereby.

General Water-Sheds.—The surveys made to ascertain the suitability of certain water-sheds to furnish water of a good quality had also been completed before the present year, and have been reported upon. The physical features, viz., the contour and elevation of the ground, the untillable areas, those covered with timber and those under cultivation, also the towns, villages, roads, etc., had all been mapped.

The sanitary features, viz., the distribution and amount of population residing upon the water-shed, its principal occupations, death-rate, disposal of sewage, extent and character of mills, factories, slaughter-houses, cemeteries, etc., had also been ascertained and entered upon the maps or described. It might be repeated here that the large scale to which the surveys were plotted, viz.: 400 feet to one inch, the comparative accuracy of the survey and the amount of detail contained on the map, render them a valuable contribution to the survey of the state, inasmuch as they cover an area of 446 square miles in Bucks, Montgomery and Lehigh Counties.

The Aqueduct at Point Pleasant is 217 feet above tide-water. The minimum flow of the river was assumed at 1,500,000,000 gallons per day (see Table, p. 361, Report of 1885). Deducting the quantity to be raised into the aqueduct, there will remain enough water to supply power equivalent to 3,640 horse-power. Assuming that the motors employed will utilize eighty per cent. of the theoretical power, there will remain 2,912 actual horse-power. Adding for friction, etc., the lift of the pumps would be 137 feet. The pumping mains are thirty inches in diameter, and the distance to the aqueduct is 600 feet. The velocity in the same is assumed to be 312 feet per second. Computing the loss by friction of the pumps at three per cent., it is found that 117,463,000 gallons can be raised into the aqueduct every twenty-four hours, during the lowest stages of the river. As it is practicable to supply a much larger quantity of water during ordinary stages of the river, and at favorable times to pump into the lower storage reservoir of the Tohickon Valley, Mr. Hering assumes the available capacity of the Delaware River at 120,000,000 gallons per day, with a slight increase of cost.

General Conclusions.—In summing up the recommendations in the report, Mr. Hering says:

"It remains now briefly to recapitulate the final conclusions that have been arrived at from the examinations described above. In making these investigations, it has been taken for granted from

the outset that the water from any point in the Schuylkill River, and from any point in the Delaware River below Trenton, will not be of a sufficiently good quality to furnish a future supply for the city, although the fact has been admitted that at present the Delaware water at Lardner's Point, within the city limits, is not only fairly good, but is likely to remain so for some time.

In looking about for an improved supply, every practicable scheme was considered. No success could be expected from a supply by artesian- or driven-wells in this locality, nor would filtering or purifying the water of the Schuylkill or lower Delaware give permanent satisfaction. The only schemes worth investigating were those, which bring to the city the water of running streams in the Schuylkill, Delaware or Lehigh water-sheds.

It required but little thought to see that the water from the streams north of the Blue Mountains would be the best available in quality, not only now, but for an indefinite future, and that this region would therefore have to be the ultimate source of water-supply for Philadelphia, and probably also for other cities lying between the mountains and the seaboard.

To obtain an intelligent opinion on the cost of such a supply, surveys and examinations were made, which showed that, inasmuch as water of good quality can be secured at less expense from nearer localities, it is not advisable at once to go to the Blue Mountains.

The Ultimate Source of Supply.—In adopting a scheme for an earlier future, this ultimate source, however, should be considered, so that the aqueducts now constructed could be available for the final source of supply. The quality of water, which it was thought best to calculate for at present, was at least 200,000,000 gallons per day, or more than double the present consumption. The elevation at which the water should be delivered was fixed at about 170 feet above datum (the height of the present basin at Wentz's Farm and the proposed basin at Cambria), because it gives the most favorable distribution for the city.

The streams offering a good water-supply nearer than the Blue Mountains are the Perkiomen Creek, a tributary of the Schuylkill River; the Tohickon and Neshaminy Creeks, tributaries of the

Delaware River; and the Delaware River itself above Trenton. In point of quality the water of the latter has been found to be the best; that of the upper Perkiomen and Tohickon Creeks comes next in quality; and that of the Neshaminy and lower Perkiomen Creeks is least good.

The Most Economical Scheme.—An estimate of the cost of obtaining Delaware water alone, indicates that above Lardner's Point, the most economical scheme is to bring it from Point Pleasant, because the river has quite a descent near this place, which materially reduces the height of pumping as compared with points lower down the river, such as Lumberville, New Hope and Yardleyville. Another advantage gained by this sudden descent is the water-power which can be developed to furnish a daily supply of 120,000,000 gallons during the dry season.

The cost of the aqueduct, pumping plant, and capitalized cost of pumping amounts to $19,622,543, if 210,000,000 gallons of water daily are pumped by steam, and to $15,475,262, if only 120,000,000 gallons are pumped by water, and the remainder by steam.

Purely gravity supplies, without pumping, can be obtained either from the Perkiomen Creek or from the Tohickon and Neshaminy Creeks combined. The latter project cannot be made to furnish a daily supply of over 156,000,000 gallons in years of minimum rainfalls. While the water furnished by the Tohickon and upper Perkiomen Creeks is good, that which is taken from the Neshaminy and lower Perkiomen, as already stated, will be of much inferior quality. Neither of these purely gravity schemes would, therefore, be quite satisfactory.

The cost of procuring a supply from the Perkiomen Creek is $13,674,493, and from the Tohickon and Neshaminy Creeks together, $13,846,662.

Finally, a combined gravity and pumping scheme is possible, by procuring water from the Tohickon Creek and from the Delaware River at Point Pleasant. The former can furnish on the average between 90,000,000 and 100,000,000 gallons per day by gravity; in minimum years only 80,000,000 gallons can be depended upon.

The Delaware River, as we have seen, can furnish 120,000,000 gallons by water-power. Both the Tohickon and Delaware waters

have been found not only to be of good quality, but much better than the waters of the Neshaminy, and particularly of the lower Perkiomen Creek.

The cost of this scheme is $12,695,941, if the water-power is utilized, and $17,717,025, if steam-power is used.

It is, therefore, clear that the best and most economical project to supply the city of Philadelphia with water is to bring to it the Tohickon water by gravity, and to pump from the Delaware River at Point Pleasant by water-power.

In order to perceive the relative values of the different schemes with still more distinctness, I have made three estimates, one for completely filling the aqueduct, one for furnishing 150,000,000 gallons, and one for only 90,000,000 gallons per day.

To supply the latter quantity of water from the Perkiomen Creek will require an expenditure of $10,495,000. In bringing 90,000,000 gallons daily from the Delaware water-shed, it is found that the Neshaminy Creek alone could furnish this amount, except during years of minimum rain-fall, at a total cost of $7,875,000. The Tohickon Creek alone, could furnish a quantity up to 90,000,000 gallons, except during very dry years, at a cost of $10,008,000. If the Delaware water at Point Pleasant is used, the cost for 90,000,000 gallons will be $12,775,000, if pumped by steam, and $9,673,000, if pumped by water-power. At Lardner's Point, the cost will be $7,064,000.

Therefore, to supply the city daily with 90,000,000 gallons of water, which is the present consumption, the cheapest project is to pump the Delaware water at Lardner's Point; the next is the Neshaminy, and the third is to pump Delaware water at Point Pleasant.

To increase the supply to 150,000,000 gallons will require a total expenditure of about $12,139,000, if the Perkiomen water only is used, and a total expenditure of about $17,635,000, if no water is taken from below Green Lane and the deficiency supplied from the eastern affluents of the Lehigh River above the Lehigh Gap.

On the Delaware areas the water stored from the Neshaminy and Tohickon Creeks together, could furnish an amount up to 156,000,000 gallons, at a cost of $13,846,652. If, instead of using he Neshaminy water, Delaware water is pumped at Point Pleasant, he cost will be $14,275,000 if steam, and $11,215,000 if water-

power is employed. To supply Delaware water only will cost, if pumped by steam at Point Pleasant, $16,355,000, and at Lardner's Point, $10,415,000.

For supplying 150,000,000 gallons daily, therefore, from beyond Lardner's Point, the project contemplating the use of both the Tohickon and Delaware water at Point Pleasant, pumping the latter by water-power, is the least expensive one.

Finally, to increase the supply to 210,000,000 gallons, the Point Pleasant scheme, as already stated, is again the most economical one, besides furnishing water of decidedly the best quality.

It, therefore, appears with sufficient clearness, I think, that whenever good water can no longer be obtained from Lardner's Point by the pumps, which it may be considered advisable to place at this point, the city should build an aqueduct to Point Pleasant, pump Delaware water by water-power, and supplement the quantity as it may become necessary, by storing the water from Tohickon Creek, first in the lower, and then in the upper, reservoir.

After the aqueduct is taxed to its full capacity, at which time it will probably be necessary to go to the Blue Mountains for an increased supply, another aqueduct will have to be built. It is premature, I think, to say definitely, at present, whether this second aqueduct, extending to the Blue Mountains, should go by way of the Delaware or Lehigh Rivers. If the South Mountain region should preserve its present character, there can be no doubt that it should extend by way of the Perkiomen Valley, and, after receiving the South Mountain water at Green Lane, follow up the Lehigh River.

The cost of this scheme, which is now relatively greater than that of others, would then probably be less. Later, the Point Pleasant aqueduct could also be carried to the mountains whenever the quality of the water, owing to the pollution from the Lehigh River, became objectionable, and its extension would then most economically be to the Delaware Water Gap.

It will be better to build two separate aqueducts in this way, than only one, with double the capacity, because, in the latter case, the risk from accident becomes greater. New York, Boston, Washington and Paris each have two; London has even more.

When the above-mentioned aqueducts shall be built, the city of Philadelphia will be supplied with the best water obtainable in Eastern Pennsylvania.

REPORT OF A SPECIAL COMMITTEE OF THE FRANKLIN INSTITUTE TO FORMULATE A PLAN FOR A STATE WEATHER SERVICE.

[*Presented at the Stated Meeting, held Wednesday, December 15, 1886.*]

At a meeting of the Special Committee to Formulate a Plan for a State Weather Service, held Wednesday, December 15, 1886, the following report was adopted, and ordered to be reported to the next monthly meeting of the INSTITUTE.

W. P. TATHAM, *Chairman*,
LORIN BLODGET, WM. H. WAHL,
M. B. SNYDER, ALEX. E. OUTERBRIDGE, JR.

THE SUB-COMMITTEE, appointed to consider the advisability of establishing a "State Weather Service" for Pennsylvania, under the auspices of the FRANKLIN INSTITUTE, and in conjunction with the United States Government Meteorological Bureau in Washington, begs leave to offer the following report.

REPORT.

Experience has proved that the practical benefits to be derived from the daily forecasts of storms, cold-waves, etc., are greatly restricted, especially in the agricultural districts, by the want of sufficient facilities for disseminating the official information promptly. Farmers, who are especially interested in these forecasts, are usually so located that the reports do not reach them in time to be available as predictions, and they are therefore of little value to this class of the community. In order to overcome this deficiency, the experiment has been tried of establishing, in several of the Western and Southern States, an auxiliary "State Weather Service," with volunteer observers located at available points working under a chief, residing at some central locality, who in turn is in daily telegraphic communication with the Government Bureau in Washington. By the aid of this organization, it is found that the weather forecasts may be much more rapidly and widely disseminated than has heretofore been practicable. The State Services already established, have proved of great value

to the citizens, and have afforded material aid to the Meteorological Bureau, in its efforts to extend its usefulness. It is at the request of the officers of this Bureau, that the FRANKLIN INSTITUTE is considering the advisability of fostering the establishment of a similar service for Pennsylvania.

The Chief Signal Officer offers to aid the work, by furnishing all blank forms, upon which the reports are written, by supplying a competent instructor, and an inspector, who will visit the stations, compare and correct the instruments, collate the reports, etc., etc.

It appears, from the statements of the officers of the Meteorological Bureau, that the State Services already established, have proved invaluable to the communities in which they are placed; and this committee is of the opinion, that a similar service would prove equally valuable in Pennsylvania, and that it is a proper subject for the careful consideration of the FRANKLIN INSTITUTE.

By means of the efficient "Railway Bulletin Service," now in operation by the different railroad companies in this state, such a system is both possible and practicable, at a very small expense. By these companies, the weather indications of the Signal Service, are daily posted at over 300 stations well located for points of distribution.

By the "Flag Weather Signals," which can be displayed at these centres, and repeated or duplicated at proper distance from each other, the entire state can soon be covered with symbols, and the indications or warnings given to every locality participating in the work.

The value of such information is sufficient, to induce the belief, that if a system were properly organized, the people would very generally aid in these displays by volunteering their services.

While the stations of the Signal Service may be numerous enough for storm and frost-warnings and general weather predictions, they are not sufficient to determine the climatic conditions of our state sufficiently for the best scientific and practical results.

They are mere outposts for general work, so far apart that numberless meteorological phenomena occur, that, being unrecorded, are lost for comparison and study.

The value of systematic and continuous records of atmospheric changes cannot be over-estimated. There is not an industry in the country that could not be benefited by them.

For this purpose, a thorough system of taking and recording observations should be organized in every county. No doubt, with proper encouragement, a sufficient number of volunteers could be found for this work, and, in a short time, such an array of climatic data might be collected, that valuable and comprehensive information might be given, concerning the meteorological condition of any part of the state.

As above remarked, several of the states have already experienced and recognized the practical benefits to be derived from a "State Weather Service," and have appropriated money to properly furnish the stations with the necessary Government standard instruments, for measuring the pressure, temperature, humidity, rain-fall, wind, etc.

This should be done by the state of Pennsylvania, as the benefits would be general.

An appropriation of $3,000 will properly equip one station in every county, and furnish means for the monthly publication of a *Weather Review*, containing the tabulated reports of the observations.

After the stations are once established, the cost of maintaining a continuous service will be slight.

The following is a price-list of standard instruments, as published by the Signal Service:

Barometer,		$30 00
Thermometers	Dry bulb,	3 00
	Wet bulb,	3 00
	Maximum,	5 00
	Minimum,	4 00
Rain-gauge,		2 50
Instrument Shelter,		5 00

For the reasons herein stated, we suggest:—

That the FRANKLIN INSTITUTE at once organize a "State Weather Service" for Pennsylvania, having for its object the collection and collation of climatic data and phenomena, and the dissemination of the weather-forecasts, storm- and frost-warnings of the Signal Service.

That the work of taking observations, disseminating forecasts, warnings, etc., be accomplished by volunteer service.

That the co-operation of railroad companies, telegraph companies, telephone companies, newspapers, and others, who can materially aid in the dissemination of information, be solicited.

That the offer of the Chief Signal Officer of the Army, to furnish a member of the Signal Corps to assist in the work, be accepted.

That an effort be made to secure an appropriation of $3,000 from the state, for the purchase of instruments and for the publication of the observations in a tabulated form.

That all institutions of learning throughout the state, be solicited to take an active interest in the collection of meteorological data and the study of the science, for practical application to the various pursuits of life.

That at least one observer be secured in every county of the state, ten of whom should take and record barometric readings.

That copies of all meteorological data relating to the state be secured and placed on file in the Central Office.

That immediate action be taken to secure observers and display-men, so that the work may be commenced, if possible, on January 1, 1887.

That, if all the work suggested, cannot be at once carried out, such portions as can be done without expense, be started as soon as practicable.

That the management of this Service be placed in charge of a committee, appointed by the INSTITUTE, with power to regulate the service according to requirements.

AT THE STATED MEETING of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, held Wednesday, December 15, 1886, the foregoing report was adopted and the Committee was continued, with instructions to carry into effect the plans proposed. (Attest.) WM. H. WAHL,

Secretary.

A NEW METHOD FOR THE ANALYSIS OF AIR AND GASES.—Otto Petterson (*Zeit. Analyt. Chemie*, **25**, 467), publishes the description of a gasometric method in which the measurements are made under constant pressure and constant temperature. For a description of this somewhat complicated apparatus, we must refer to the original memoir. W. H. G.

The HAMMER-BLOW in LOCOMOTIVES.

An ordinary locomotive, when balanced for the horizontal action of the moving parts by means of counter-weights disposed within the rim of the driving-wheel, cannot possibly be balanced in a vertical direction, excepting so far as the moving-gear has a vertical component of motion. Thus, the coupled-wheel of an ordinary four-coupled engine may be counter-weighted to balance the half-weight of the coupling-rod, for this revolves, in a sense, wholly about its crank-pin, but the driver, which is counter-weighted for the piston, cross-head, etc., is evidently out of balance vertically, owing to the fact that the piston and all parts having a rectilinear motion only, have no vertical component of motion, and so do not counteract the vertical action of the balance-weight in the rim. It is thus easily seen that the action of these parts would be best balanced by an equal and opposite force generated by similar moving parts. Theory and experiment alike show that a pair of engines working onto the same crank-pin and with their cylinder-axes inclined at right angles to each other are arranged most advantageously. It is difficult to see how such an arrangement could be applied to a locomotive, and even if applied, there would be set up so many other disturbing actions, due to inclined cylinders, as to more than neutralize any benefit obtained. It is, indeed, difficult at first sight to see in what way the vertically-unbalanced force in the wheel-rim can be eliminated in a practical manner.

Dismissing the first suggestion of inclined cylinders at right angles, as unsuited to the question of *locomotive* balancing, let us proceed to inquire whether the ordinary engine can be made to exert an even pressure on the rails at every period of the wheel revolution. The so-called "hammer-blow" in locomotives is the irregularity of the pressure exerted between the wheel and rail, which arises from the vertically-unbalanced action of the counter-weights placed in the wheel to neutralize the horizontal action of the piston and other moving parts. This vertical action of the balance-weights, as stated above, is not counteracted by any corresponding action in the moving parts, for of these the connecting-rod alone has any vertical movement due to the rotation of that

end which is attached to the crank-pin. The big end, then, directly, and the remainder of the rod to a lesser degree, has some influence in a vertical direction, but there still remains a large unbalanced action corresponding with the weights of piston, rod, and cross-head and part of the connecting-rod. Hence, when the balance-weight is at its nearest position to the rail, the vertical action adds to the pressure on the rail, whilst when at the opposite, or upper side of the wheel, a relief of pressure occurs, and it is this alternate addition and relief which constitutes the supposed hammer-blow. At high speeds, this action certainly partakes of the nature of a blow, but may be represented by a wave-line diagram, as in *Fig. 1*, where the mean weight on a wheel is being represented by the ordinates between the two parallel lines (say ten tons). The alternate variation of pressure is shown by the curved line, the space from crest to crest of wave being one

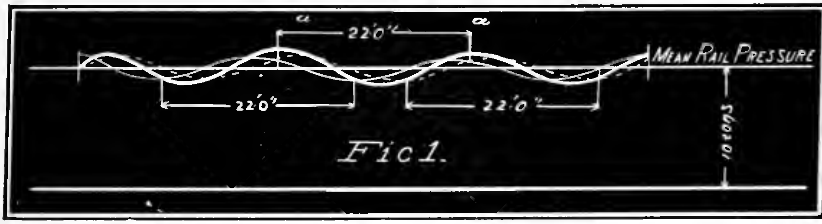


FIG. 1.

circumference of a driving-wheel, or twenty-two feet in the case of a seven-foot wheel.

In the diagram, the ordinates to the thin, full line, represent the rail pressures at every point of, say, the driving-wheel on the left side of an engine, the dotted curve giving the corresponding measurements for the right side, whilst the thick curved line is the mean of the two wheels, and serves to illustrate the action of the hammer-blow upon a bridge.

In order to fix the mind, let us assume the case of a seven-feet diameter single engine, with an unbalanced vertical action, resulting from forty-three pounds of a counter-weight acting at a radius of thirty-two inches, this weight being the excess left unbalanced by the vertical action of the connecting-rod, the total balance-weight perhaps, being eighty-six pounds. The centrifugal force due to forty-three pounds at sixty miles an hour, may be found by the well known formula, $F = \cdot 00034 . w . r . N^2$, when N, in this case, is

240 Then $F = 2{,}240$ pounds fully, say, one ton, which acts alternately upwards and downwards, with a difference of two tons, which will be the difference in length between the longest and shortest ordinates to either primary diagram in *Fig. 1*.

Now, an investigation into the deflection due to one ton load upon a spring twenty-four inches span, composed of twelve plates $5 \times \frac{3}{8}$ inches, and a top plate, $5 \times \frac{1}{2}$ inches, will show such deflection to be about one-sixteenth inch. The downward action of the balance is resisted by the rail, and cannot affect the steadiness of the engine. The upward action is resisted by the weight of the engine, acting through the springs. It must serve, then, to support the weight of the engine, and by so doing, it relieves the weight upon the rail, but as it now exceeds the weight of the engine, it cannot affect the steadiness in any way. The net result is simply a constantly varying pressure on the rail on either side of the mean.

We have just seen that one ton represents a spring deflection of one-sixteenth inch. It thus appears that an arrangement whereby the spring could be caused to vibrate one-sixteenth on each side of its mean deflection, would serve to equalize the rail pressure at the speed of sixty miles per hour. This spring action might be brought about by placing the wheel upon the axle eccentrically to the amount of one-sixteenth inch, the eccentricity being so arranged that at the counter-weight side of the wheel, the radius from the axle centre to the wheel tread, would be 3 feet $5\frac{15}{16}$ inches, whilst on the side opposite the radius is 3 feet $6\frac{1}{16}$ inches.

Then as the wheel revolved, or rolled along the rail surface, the axle centre would be raised and lowered through one-eighth inch, and with it, of course, the axle-box and spring-pin, so causing a constant action of the spring of one-eighth inch, representing the alternate addition and subtraction of one ton of load.

This, of course rests, on the assumption that the engine remains fixed in a vertical direction, and does not partake of the action of the springs.

The practical action, however, would not altogether conform to the assumption, and there would be to some extent a transference of the "hammer-blow" action to the other wheels of the machine, though to a very reduced amount, and also, to some extent, an absorption of the spring action by the inertia of the general mass of the locomotive. It has been stated above, that the excess of action on the rail cannot affect steadiness of running.

The relief action, however, of one ton, when in excess of the weight of the wheel and half-axle, etc., would lift the wheel from the rail, and its excess above the wheel-weight, etc., with centrally-fixed wheel, is resisted by the spring. A little thought will show that this can have no action in deflecting the spring, its action being merely to support the weight of the engine, relieving the rail-load to that amount. With an eccentrically-fixed wheel, however, the speed at which the centrifugal action was calculated would require to be constant. It may, however, be taken for granted that at low speeds, such as four or five miles per hour and upwards, the irregularity of action due to the radius difference of one-eighth would not be more severe than the present pressure variation existing in a normal engine. In the example of this paper, with seven-foot wheels the "blow" occurs every quarter second in each wheel, at sixty miles velocity. The two wheels together give blows following each other in one-sixteenth and three-sixteenths of a second respectively, the cranks, however, being at right angle. With six-foot wheels, the action is more severe and oftener repeated (F varying with r and N^2). Here we see one advantage attendant on the use of large wheels which may perhaps explain why in America the question of the hammer-blow has received far greater consideration than in England, where wheels of seven and eight feet are employed to run at speeds which in America are run with wheels of five feet and 5 feet and 6 inches. Hence the hammer-blow is at least of double the intensity in America, compared with England, and varies inversely as the square of the wheel diameter.

Assuming our reasoning to be correct in principle, it is clear that for every speed there is a certain eccentricity which will render nugatory the present unbalanced counter-weight action. It is by no means uncommon to find the eccentrics of steam-engines made compound, the main eccentric driving the valve, being seated upon an inner and smaller eccentric on the shaft. By this device, the throw of the combination may be varied between limits by any desired amount, depending upon the angular displacement of the eccentrics relative to each other.

The application of this principle to the axle-seat of a locomotive wheel would, if it could be safely and practically effected, supply a means of giving to such driving-wheel any desired eccentricity

between nil and a maximum of, say, the above calculated one-eighth inch. A suitably designed governor, revolving at a speed proportionate to the forward velocity of the engine, could be so arranged as to vary the eccentricity to suit the speed, exactly as in the case of the steam-engine.

The writer, however, does not propose this as a practical solution of the question, so much as an indication of the principles involved. It does, however, appear that a certain speed might be calculated for, and a fixed eccentricity given to suit the speed at which the engine will run. So arranged, an engine would run its calculated thirty, forty, sixty or seventy miles per hour with perfectly even rail pressure, and at no speed would this vary so much as in a normal engine.

Fast express engines would be best ex-centred at, say, a mean speed of sixty, local trains for forty miles, whilst freight engines would count for, say, twenty. We have seen that in a large wheel there is a total action of two tons; this seems severe, but it does not appear probable that such action can be very dangerous to bridge structures. The real action of the hammer-blow, as shown by the diagram, is gradually imposed; excess and deficiency of rail-pressure and the mean culminations of the two wheels, as shown by the thick lines, may be taken as the true vibratory cause. Should these culminations synchronize at the train speed with the period of oscillation of the bridge, the effect might be serious, especially if the culminations also at the same time coincided with floor-beams. Any want of coincidence between these three, might entirely nullify vibration, by their mutual interferences. Such a concomitancy of vibration, panel length, and culminations *a*, *a*, as above described, is not likely to occur, and in considering the question of bridge vibration, it would appear that if anything be done, it should be in the direction of so arranging panel lengths, as not to correspond, at average speeds of train, with the period of vibration of the bridge, or with wheel circumferences—this latter possibly the better safeguard of the two.

In conclusion, the writer would state that there appears every reason to believe that the vertically unbalanced action of locomotives is very severe. The writer's house is only forty yards from the centre of a double-track railroad, on which some trains pass daily at a speed of sixty miles or upwards.

The vibration set up apparently coincides with the wheel revo-

lutions and is very severe and of a vertical nature in the ground, but great differences are observable in different engines.

Heavy four-coupled engines set up greater vibrations than single engines. The four-coupled wheels are from 5 feet 6 inches to 6 feet 6 inches diameter. The single engines have seven-foot wheels and also inclined cylinders. Now, whatever may be the faults of inclined cylinders, it is easy to see that the vertical action of the steam against the cylinder-covers and through the connecting-rod, upon the rail, will serve to counteract the "hammer-blow," which must also be less severe than in the smaller wheels.

These appear to be the chief reasons why the vibratory actions of the small wheels is greater, apart from their greater frequency.

In submitting his views of the question for the consideration of American engineers, the writer is confident they will receive fair treatment and obtain a hearing, perhaps, better than they would receive in England, where conservatism of ideas is more marked. With the apparatus illustrated in the JOURNAL OF THE FRANKLIN INSTITUTE, it might well be worth while to experiment with eccentric wheels; determining the amount needful in an actual case, to counteract all variation on the dynamometer. The effects due to obliquity of connecting-rod would require elimination by taking diagrams also with centrally-fixed wheels. The difference between these and the diagrams from the ex-centred wheels would mark the eccentric action. Such a series of experiments would be of great interest and service to scientific engineers. The writer anticipates that the final result of any thorough inquiry will be in favor of larger wheels towards which American practice is now tending, and which certainly appear to show good cause for their existence in the already-mentioned greater attention given to the "hammer-blow" in America than in England.

P. S.—It might be added, that as the variation of pressure on the rail is shown by a wave-diagram, it cannot amount to a *blow* and cannot therefore possibly injure the rails, except in so far as they are generally weak. For "how does the rail know" that the heavier *pressure* at the time the supposed *blow* is taking place is not due to a generally heavier locomotive without a blow. At most, the effect of the blow is to increase the pressure on the rail about twenty per cent. in places and reduce it twenty per cent. in others. (This with, say, five and one-half-feet wheels.) Hence a rail twenty per cent. stronger is needed for the increase may come anywhere. With such a stronger rail, the hammer-blow would have no further effect than a perfectly balanced wheel on the normal rail. W. H. BOOTH.

Huxton, near Manchester, England, November, 1886.

ELIZABETH THOMPSON SCIENCE FUND.

This fund, which has been established by Mrs. Elizabeth Thompson, of Stamford, Conn., "for the advancement and prosecution of scientific research in its broadest sense," now amounts to $25,000. As the income is already available, the Trustees desire to receive applications for appropriations in aid of scientific work. This endowment is not for the benefit of any one department of science, but it is the intention of the Trustees to give the preference to those investigations, *not already otherwise provided for*, which have for their object the advancement of human knowledge, or the benefit of mankind in general, rather than to researches directed to the solution of questions of merely local importance.

Applications for assistance from this fund should be accompanied by a full statement of the nature of the investigation, of the conditions under which it is to be prosecuted, and of the manner in which the appropriation asked for is to be expended. The applications should be forwarded to the Secretary of the Board of Trustees, Dr. C. S. Minot, 25 Mt. Vernon Street, Boston, Mass., U. S. A.

(Signed) H. P. BOWDITCH, *President.*
WM. MINOT, JR., *Treasurer.*
FRANCIS A. WALKER.
EDW. C. PICKERING.
CHARLES SEDGWICK MINOT, *Secretary.*

ON THE PRESENCE OF OXYGEN IN SILVER.—Van de Plaats (*Rec. de Trav. Chim.*, **5**, 212) has critically reviewed the work of Dumas, from which that chemist was led to conclude that silver always retains oxygen after fusion in presence of that element. The silver was heated to ebullition in an unglazed crucible, by the application of an oxy-hydrogen blow-pipe flame to its surface. The almost boiling metal was then poured into cold water in a tall, cylindrical vessel, at the bottom of which was placed a silver crucible. About ten grammes of this granulated silver was then heated to the softening point of Bohemian glass, successively in currents of air, hydrogen and carbon-monoxide, and subsequently in a vacuum, the gases in each case being carefully purified. The experiments showed that silver purified according to the method of Stas does not sensibly decrease in weight when heated in a vacuum to 600° C. for about three hours, and the weight of the silver did not vary by heating in the gases named. W. H. G.

CAN THE ORIGINAL REIS TELEPHONES TRANSMIT INTELLIGIBLE ARTICULATE SPEECH?

BY PROF. EDWIN J. HOUSTON.

A brief note on "Some Additional Facts Concerning the Reis Articulating Telephone," published by me in the JOURNAL OF THE FRANKLIN INSTITUTE, July, 1886, has called forth the following correspondence from Dr. Theodore Stein, and Mr. John R. Paddock, which is here given:

From this correspondence, it will appear that Dr. Stein calls in question the possibility of transmitting articulate speech by the use of the original apparatus referred to by Mr. Paddock in the note above-mentioned.

Although the author has not personally repeated the experiments of Mr. Paddock with the original apparatus of Reis, yet he is disposed to give full credence to the statements of Mr. Paddock, because he (the author) had, prior to the publication of Mr. Paddock's letter, held an almost uninterrupted and quite intelligible conversation, continuing for some five or six minutes, in which questions and answers were given and received, by the use of a transmitter, which was an exact reproduction of the Reis bored-block transmitter, and employed the platinum contacts found on the Reis apparatus; and also because he does not see any essential structural differences between this form of transmitter and that in extensive commercial use to-day by the Bell Telephone Company.

Although the real point called into issue by Dr. Stein's correspondence is limited to the practicability of one of the first of the Reis instruments as an articulating telephone transmitter, yet, it will be observed that he acknowledges that the later forms of Reis apparatus—forms described and given to the world long prior to the date of Bell's alleged invention of the articulating telephone—will transmit intelligible, articulate speech. This being the case, even if Dr. Stein established his point as to the inoperativeness of the original Reis instrument, which we fail to see that he has done, it still remains a fact that an instrument called by Reis, its inventor, a telephone, and claimed by him as an instrument intended to transmit articulate speech, employed by him to

transmit articulate speech, and heard by others during Reis's life-time to transmit such speech, *still transmits such speech*, then Reis, and not Bell, is the real and true inventor.

It is perhaps, difficult for one not living in America to credit the extent to which, at the present moment, the courts have sustained the legality of Mr. Bell's claims to the invention of the articulating telephone. If they had only awarded to him patent-rights for improvements on the electrical transmission of speech, the point we have made here would lose its significence; but in America, Bell at present is held, from a legal standpoint, to be the first and only inventor of the telephone, and is awarded *the sole legal rights to employ electricity in the transmission of speech.* This we contend, in view of the above, is certainly at fault from a scientific standpoint, and we are disposed to believe from a legal standpoint also.

We will permit the correspondence, however, to speak for itself:

FRANKFURT A. M., den 21. Juli, 1886.

HERRN PROFESSOR EDWIN J. HOUSTON, IN PHILADELPHIA.

GEEHRTER HERR!—Ich erhielt vor einigen Wochen einen Artikel von Ihnen, betitelt: "Some Additional Facts Concerning the Reis Articulating Telephone," und erlaube mir Ihnen dagegen einen in No. 7 meiner Zeitschrift '*Elektrotechnische Rundschau*' enthaltenen Artikel zu senden, aus welchem Sie meine Ansichten über den vorliegenden Fall ersehen können. Ich würde Ihnen sehr dankbar sein, wenn Sie mir eine Mittheilung (in englischer Sprache) zukommen lassen wollten, ob Sie sich von den Angaben des Mr. Paddock persönlich überzeugt haben, denn ich kann mir nicht denken, dass man mit dem Instrumente, welches ich selbst früher besessen habe und mit welchem Mr. Paddock seine Experimente machte, in der Weise, wie in Ihrem Artikel geschildert, ganze Sätze in deutlicher Vernehmbarkeit übermitteln konnte. Mir persönlich war es, obwohl ich den Apparat viele Jahre besass, niemals möglich, mit demselben artikulirte Worte zu übertragen. Auf der Münchener Elektrizitäts-Ausstellung, 1882, woselbst ich den Apparat ausgestellt hatte, beschäftigten wir uns bei dem betreffenden Prüfungen mit grosser Mühe, mit dem Apparate gesprochene Worte zu übermitteln, es gelang uns aber nicht. Auch ist mir nicht erinnerlich, je gehört zu haben, dass Professor Böttger oder Reis selbst mit diesem Instrumente Worte übermittelt hätte. Ich habe zwar selbst mit anderen Apparaten von Reis im Jahre 1862 übermittelte artikulirte Worte an dem Reis'schen Receiver gehört, jedoch war dies mit dem vielfach verbesserten Instrumente, welches in meiner Zeitschrift '*Elektrotechnische Rundschau*,' Band I, No. 4, Seite 55, Figur 7, (in der Bibliothek des FRANKLIN INSTITUT vorhanden) abgebildet ist.

Ich sehe Ihren betreffenden gefälligen Nachrichten entgegen und zeichne,

mit vorzüglicher Hochachtung,

DR. THEODOR STEIN.

Translation.

FRANKFURT A. M., July 21, 1886.

PROFESSOR EDWIN J. HOUSTON, PHILADELPHIA.

DEAR SIR:—I received, several weeks ago, an article of yours, entitled "Some Additional Facts Concerning the Reis Articulating Telephone," and, in return, I take the liberty of sending you an article, which appeared in No. 7, of my journal, the *Elektrotechnische Rundschau*, from which you will perceive what my views are on the subject under discussion. I will be greatly obliged if you will inform me whether you have personally satisfied yourself of (the accuracy of) Mr. Paddock's declarations, for I cannot think (it possible), with the instrument that formerly was in my possession and with which Mr. Paddock made his experiments, that anyone should have been able to transmit entire sentences intelligibly, in the manner described in your article. Although I had possession of the apparatus for many years, I was never able to transmit articulate speech with it. At the Electrical Exhibition in Munich, in 1882, where I exhibited the apparatus, we made the greatest efforts, while the tests were being conducted, to transmit spoken words with the apparatus—but in vain; and I do not remember ever to have heard that Professor Böttger, or Reis himself, had succeeded in transmitting speech with this instrument. With other instruments of Reis, in 1862, I have heard spoken words at the Reis receiver, but this was with the instrument of much improved pattern, which is illustrated in my journal, the *Elektrotechnische Rundschau*, Volume I, No. 4, page 55, and which you may find in the Library of the FRANKLIN INSTITUTE.

Anticipating your courteous advices in the case, I subscribe myself,

With high esteem,

(Signed) DR. THEODOR STEIN.

ELEKTROTECHNISCHE RUNDSCHAU,
Redaktion · Kaiser Strasse 25, Frankfurt a. M.

FRANKFURT A. M., den 23. Oktober, 1886.

HERRN PROFESSOR EDWIN J. HOUSTON, IN PHILADELPHIA.

SEHR GEEHRTER HERR!—Ich habe durchaus nichts dagegen einzuwenden, wenn Sie den Ihnen am 21. Juli d. J. geschriebenen Brief veröffentlichen.

Trotz Ihrer gefälligen Mittheilung, dass Sie selbst keinen Zweifel in die Angaben des Herrn Professor Paddock setzen, muss ich bei meiner Behauptung stehen bleiben, dass man mit dem Apparate, welchen ich Herrn Professor Thompson überlassen habe und den Herr Professor Thompson an die Overland Telephone Company weiter gegeben hat, nicht, wie mit den neueren Bell-Telephonen, Worte oder ganze Sätze, auf irgend eine Entfernung, auf die man nicht durch direkte Sprachvermittelung hören kann, zu übertragen vermag. Solches ist nur mit den Reis'schen Telephonen zweiter Form möglich (abgebildet in Thompson's Buch: *Philip Reis, Inventor of the Telephone*, Seite 86), weil man an diesen Apparaten die Membran beliebig spannen kann, und weil hier der Platinkontakt nicht, wie bei meinem, Herrn Professor Thompson überlassenen Apparate, etwas von der Membran absteht, sondern direkt nach dem Gesetze der Schwere auf der Membran ruht, mithin hier

keine Stromunterbrechungen stattfinden, sondern nur Stromschwankungen, wie solches das Desiderium bei Hervorbringen von artikulirten Worten oder Sätzen ist.

Die kürzlich publicirte Beobachtung von Francis E. Nipher, dass man bei einer bestimmten Spannung der Membran mittelst des Reis'schen Telephons Worte übertragen könne, halte ich für vollkommen richtig und bin überzeugt, dass jedes Mal, wenn, wie vor 25 Jahren, Worte oder kleine Sätze mit dem Reis'schen Telephon zweiter Ordnung übertragen haben, die Membran richtig gespannt war; es war immer ein Zufall, wenn dies geschah, da Reis selbst in den Vorträgen über sein Telephon auf die richtige Spannung der Membran kein besonderes Gewicht gelegt hatte.

Wenn Sie auch diese Mittheilungen im JOURNAL DES FRANKLIN INSTITUTS publiciren wollen, habe ich nichts dagegen einzuwenden.

Ich bin mit vorzüglicher Hochachtung,

Ihr ergebenster DR. STEIN.

Translation.

ELEKTROTECHNISCHE RUNDSCHAU,
Editorial Office: Kaiser Strasse 25, Frankfurt a. M.

FRANKFURT A. M., October 23, 1886.

TO PROFESSOR EDWIN J. HOUSTON, IN PHILADELPHIA.

DEAR SIR:—I have not the slightest objection to the publication of my letter to you, dated July 21, 1886.

Notwithstanding your statement that you have no reason to doubt the accuracy of the declaration of Professor Paddock, I must stand by my assertion, that, with the apparatus which I gave to Professor Thompson, and which he subsequently gave to the Overland Telephone Company, it is not possible, as it is with the more recent Bell Telephone, to transmit words or whole sentences to any distance beyond that at which the spoken words may be heard directly. Such transmission is only possible with the Reis telephone of the second form (illustrated in Thompson's book: *Phillip Reis, Inventor of the Telephone*, page 86,) for the reason that in this apparatus the membrane may be tightened to any extent, and also because in this, the platinum-contact does not stand-off somewhat from the membrane, as in the apparatus which I gave to Professor Thompson, but rests directly upon the membrane by gravity. By reason of this, there are here no interruptions of the current, but only fluctuations (undulations) in it, which is the desideratum for the production of articulate words or sentences.

I consider the recently-published observation of Francis E. Nipher, that, by giving the membrane a certain tension, it is possible to transmit words with Reis's telephone, to be quite correct; and I am convinced that every time we succeeded, 25 years or more ago, in transmitting words or short sentences, with the second form of the Reis telephone, the membrane had just the right tension. It was always an accident when this happened, for Reis himself, when lecturing on his telephone, attached no particular importance to the proper tension of the membrane.

Should you wish also to publish this communication, you are at liberty to do so. I am with high esteem, etc., DR. STEIN.

A careful perusal of Dr. Stein's correspondence will show that while he acknowledges that the original apparatus referred to is the apparatus now in the possession of Mr. Paddock, and with which Mr. Paddock tried these experiments in controversy, he denies that such apparatus can possibly transmit articulate speech. This denial is based on the fact that Dr. Stein himself utterly failed to transmit articulate speech with this apparatus although he repeatedly endeavored to do so. This we submit may be sufficient reason for Dr. Stein to call into question the probability of the correctness of Mr. Paddock's experiments, but it is not sufficient to permit him to question the possibility of such experiments, unless he can point to some sufficient reason, based on the nature of the apparatus employed, which would render the accomplishment of such results impossible.

In looking for the cause of Dr. Stein's failure to transmit articulate speech with the original Reis transmitter, we have read his letters, especially that of October 23d, with great care. Not willing to take our own translation, we have asked Dr. Wm. H. Wahl, the Secretary of the Franklin Institute, to give a literal translation of the same, which he has kindly done.

Dr. Stein himself bases the alleged inoperativeness of the original instrument on the structure of its contact-point. Speaking of the Reis telephone of the second form, which is similar to that made by Koenig, of Paris, he says that transmission of speech is only possible with this form, "because in this, the platinum-contact does not stand-off somewhat from the membrane, *as in the apparatus which I gave to Professor Thompson* (our italics), but rests directly upon the membrane by gravity."

This structural peculiarity will be better understood from an inspection of *Fig. 1*, the form referred to in Dr. Stein's letter. Doubtless here is the cause of Dr. Stein's failure. If, by the above quotation, he is to be understood as meaning that the platinum-contact stands off from the membrane in the sense of not touching it, when no speech is being transmitted, then no further inquiry need be made as to the cause of failure. He has failed, because of his ignorance of the structure of the apparatus with which he is experimenting—an ignorance which is inexcusable in the light of Reis's published statements, or of the published statements of his contemporaries. Dr. Stein fails because he is experimenting *with*

an open-circuited transmitter. That the apparatus was never designed to be employed in this manner, the following translation of an article by Prof. Böttger, in the *Polytechnisches Notizblatt,* respecting a Reis transmitter of this form, will clearly show :

"A little light box, a sort of hollow cube of wood, has a large opening at its front side and a small one at the back of the opposite side. The latter is closed with a very fine membrane (of pig's smaller intestine) which is strained stiff. A narrow springy strip of platinum-foil, fixed at its outer part to the wood, touches the membrane at its middle; a second platinum strip is fastened by one of its ends to the wood at another spot, and bears at its other end a fine horizontal spike, *which touches the other little platinum strip where it lies upon the membrane*" (the italics are my own).

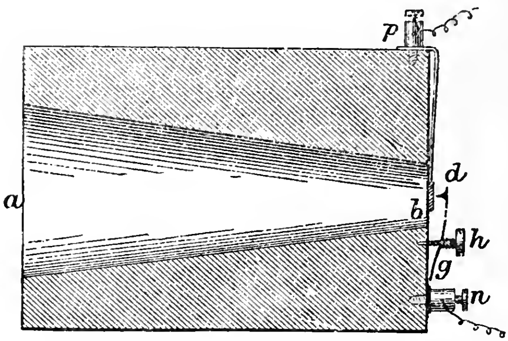


FIG. 1.—Bored-block Transmitter.

So also in a description of the Reis-Legat apparatus, published in the *Zeitschrift des deutsch-österreichischen Telegraphen-Vereins* 1862, the following statement is made bearing on this point: "In the condition of rest, the contact, *d g*, is closed, and a delicate spring, *n*, holds the lever firmly in the position of rest."

It is so difficult for us to believe that Dr. Stein could have so blundered as to experiment with an open-circuited apparatus that we have endeavored to find some other interpretation for the passage before quoted. We have therefore tried to construe his meaning to be that in the earlier form of apparatus the platinum-contact, being supported by a spring, stands off from the membrane more than it does in the later form, where it rests directly against the membrane by the action of gravity. The antithesis of

resting directly on the membrane, to the standing off of the same is, however, in our opinion, in the way of such an interpretation. Nor are we clear whether Dr. Stein merely intends to contrast the action of gravity with that of a spring, and to say that the latter is far more prompt in its action, and that its use is therefore attended with fewer breaks in the circuit than is the spring. But such a difference is one of degree rather than of kind, and the degree can be made almost imperceptible if the regulating-screw *h*, *Fig. 1*, provided for the purpose, is employed to give the spring such elastic pressure as to enable it to freely follow the movements of the diaphragm. Does Dr. Stein understand the function of this screw, and if he does, where is the pertinence of his remarks above quoted as to the operativeness of the one form of apparatus and the inoperativeness of the other?

As to Dr. Stein's insinuations respecting the "distance beyond that at which the spoken words may be heard directly," we are unwilling to insult the intelligence of our readers by stating that in experiments of this character, where the honesty of the experimenter is assured, any uncertainty from such source is impossible.

We here append the following letter from Mr. Paddock, in which he describes at greater length, experiments with the particular form of the Reis apparatus in question.

November 29, 1886.

Prof. E. J. Houston,

Franklin Institute, Phila.

The communications of Dr. Stein relative to my experiments with the original Reis instruments having been called to my attention, I take pleasure at this time in furnishing additional information in regard to the same, which I had already promised to do in a former letter. At that time, I had succeeded in transmitting a sentence in English of twenty-three words while the instruments were operating in exact conformity to the method Reis describes in his lecture before the Physical Society of Frankfort A.-M. Since then, the extent to which these instruments will transmit articulate speech has been farther investigated and the results carefully tabulated.

These results show that while this first form of the Reis telephone is a very imperfect instrument, still it is able to transmit certain words and sentences in common use, in our language to-day and to this extent at least is capable of transmitting articulate speech. In order that my meaning may be made the clearer, I will give examples of words which have been transmitted, indicating the elementary sounds of speech to which the instruments responded, and those to which they did not; and will also append copies of accurate drawings of the instruments themselves. (*See Figs. 2 and 3.*)

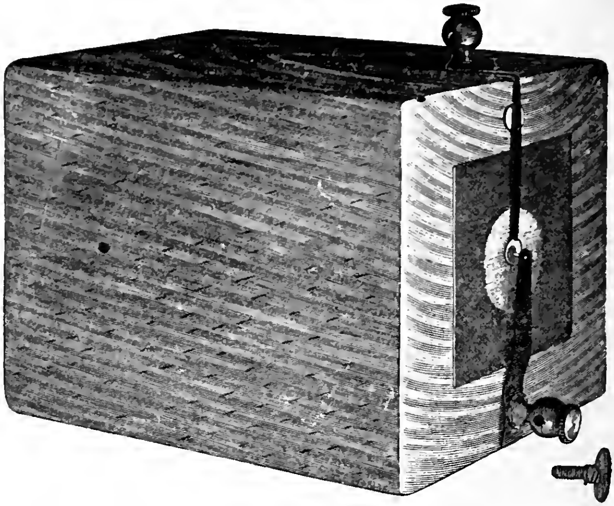


FIG. 2.

Spoken at the Transmitter.	*Heard at the Receiver.*
Rŭn	Rŭn
Sŭn	—ŭn (s, could not be heard)
hăt	—ăt (h, could not be heard)
păt	păt
Căt	kăt
better	better
letter	letter
Fetter	—etter (F, could not be heard)
talking!	talking
Walking!	Walking
Shouting!	———ing (shout, not heard)
Phonograph!	Phonograph
Telegraph!	Telegraph
Philadelphia!	Philadelphia
Boston!	———ŭn
New Jersey!	Nŭ— ———
Maryland!	——·——
Virginia!	————
Ohio!	O–io
Connécticút!	Connecticut
The Indianna State Bar proposes to hold a meeting.	—— Indianna ——— —— ——— — —— ——ing.
Governor Hill was elected by ten thousand majority!	Gov—nor —— —lected — ten thousand majority!
Did you get my telegram I sent you yesterday?	Did you get my telegram I sent you yesterday?

In order to obtain such results as these a number of conditions must be complied with, which require much time and patience and involve many dis-

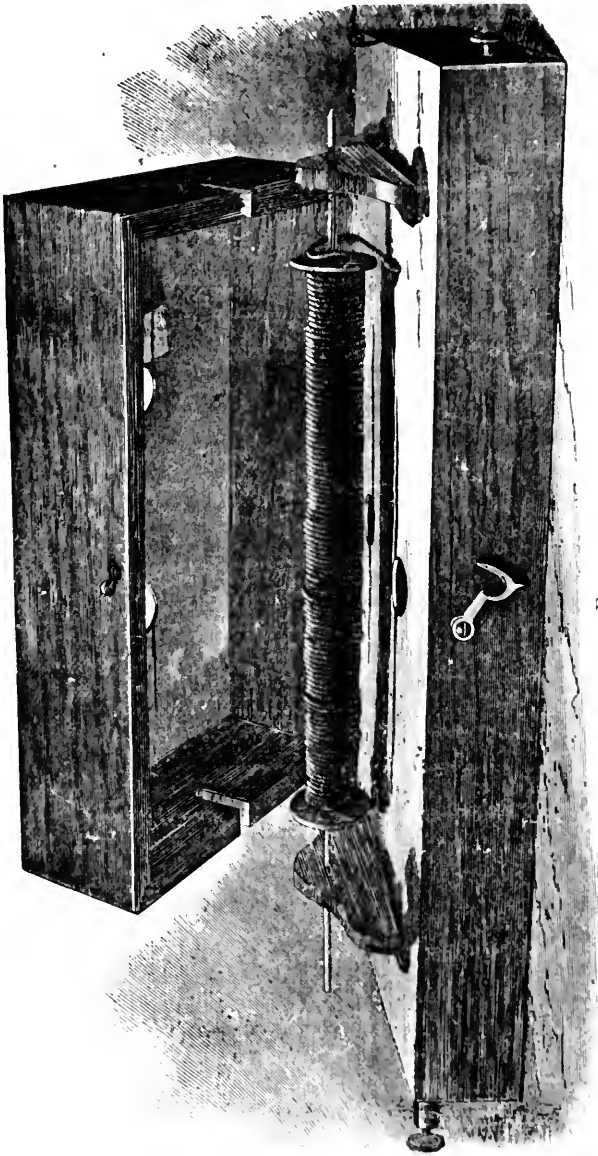


Fig. 3.

couraging failures, in view of which it is not surprising that conflicting statements should exist regarding the efficiency of the instruments. In the first place, the knitting-needle receiver, in order to be heard distinctly, requires at

least five or six times the *Electro-Motive-Force* used with ordinary magneto receivers, otherwise many of the smaller vibrations will be lost to the ear—simply because they are beyond the reach of hearing. The resistance of the circuit also must be kept very low indeed. The reason for this is evident when we consider that all sounds of the receiver are caused by the variations in the electric current produced at the transmitter, and that these variations must be of great amplitude *in order to render such a receiver as the Knitting-Needle—audible.* Hence it is desirable to concentrate the greater part of the resistance of the circuit at this point. It is also evident that any attempt to obtain louder sounds from the receiver by increasing the battery, while resistances at all comparable with that at the transmitter remain in the circuit, will be useless.

To obtain the best results, the instrument should be spoken to in *an exclamatory tone of voice* and with distinct articulation, so as to cause the membrane to vibrate strongly and rapidly. I had myself been accustomed to speak in well modulated tones of the voice until I found by numerous trials that the former method produced the best results in this instrument. This has not been my experience with other forms of the Reis instruments.

The requisite tension of the membrane I have found to be nécessary as Dr. Stein remarks. But in the absence of any mechanical means, such as is furnished by the later forms of the Reis apparatus, I have obtained the desired tension of this membrane by exposing the instrument for a short time to a dry and warm current of air, or still better, to the direct rays of the sun, without detaching the membrane in any way from the wooden block to which it is secured. Under these conditions any degree of tension can be obtained which is desired, and care only has to be exercised that this tension shall not be *too great?*

The general impression has been that the tighter this membrane can be stretched the more nearly it approaches the condition of a metallic diaphragm; but this is not the case, as an animal membrane under great tension assumes a fundamental vibration of its own, which seriously interferes with its transmitting all the vibrations of the voice.

In the later forms of the Reis transmitter (with which I am quite familiar) the use of gravity in causing the weight of the hammer-piece to regulate the movement of the contact-point is, no doubt, a decided advantage over the elasticity of a metal strip used in this first form, because in this form there is a liability to irregular breaks in the electric current. Notwithstanding this, when such breaks are *timed and spaced by the action of the voice itself,* they do not of necessity prevent the transmission of speech, as is evidenced by my experiments in which the contacts are heard to part, and sparks are seen to pass between them. The explanation in this instance may be that when spoken to in the manner described, the membrane in its returning phase of vibration does not reach the initial point before it is again forced forward by a new wave of condensation; and thus the breaks in the electric current are of exceedingly short duration, and correspond as to point of time with the air vibrations causing them—in other words they are timed and spaced by the voice itself.

To my own mind there can be no sharply defined line drawn between the

first and second form of the Reis instruments whereby the sound can be said to transmit speech but the first not; photographic records of the motions of the contacts in a modern transmitter show that *breaks* are continually occurring during the transmission of speech, and recent experiments of my own indicate that there is but *one method* common alike to all forms of Reis and to modern battery transmitters, and that this method may involve undulations, interruptions and breaks at successive moments while transmitting artificial speech in all of its complex forms.

In conclusion I would say that in these tests with the Reis instruments no communication of direct speech was possible—the transmitter and receiver being in distant buildings—the experiments are open for verification to the scientific public. With esteem and regard,

Very truly yours, JOHN R. PADDOCK.

It will be noticed that the condition insisted on by Mr. Paddock, as essential to the successful use of this form of Reis transmitter, viz., "The resistance of the circuit must be kept very low indeed," differs radically from the manner in which Dr. Stein appears to have used the instrument, viz., with the platinum-contact borne by the spring standing off some little distance from the platinum-contact placed on the membrane, that is to say an open circuit and with a practically infinite resistance in the circuit. Under such conditions of course Dr. Stein must, of necessity have failed in attaining transmission of articulate speech.

Since placing the above correspondence in the hands of the editor of the JOURNAL OF THE FRANKLIN INSTITUTE, for publication, I have received from Dr. Stein an article concerning my publication before referred to, criticising both my printed references thereto, and Mr. Paddock's experiments.

In this article Dr. Stein disposes of the question apparently to his entire satisfaction with the remark that such an instrument cannot produce undulatory currents, and therefore cannot, of course, transmit speech. In America, where this, by no means substantiated, opinion has been so carefully and industriously disseminated in the non-scientific community, by the legal friends of Bell, we would not be surprised at its reiteration, but coming, as it does, from Germany, we must confess to considerable surprise.

Dr. Stein adds nothing, in our opinion, in this article in the way of substantiating his assertions. Besides indulging in personalities, and impugning motives, the article is so lacking in what we may call the amenities of scientific controversy, that we do not think it worth our while to notice it further than what we have done above.

Central High School, Philadelphia, December 8, 1886.

BOOK NOTICES.

SHORT LECTURES TO ELECTRICAL ARTISANS. By J. A. Fleming, M.A., D. Sc. E. & F. N. Spon. 1886.

In this excellent little book the author has taken a new departure from the old stereotyped explanations, descriptions, cuts, etc., which have been so often repeated and published that they are now of little interest save as historical relics. He treats the subject in a new and apparently original way, which adds greatly to clearness and increases the interest of the book to readers not already versed in the subject. As the title implies, the book is for electrical artisans and is entirely free from abstruse mathematical expressions, formulæ or complicated theories, the subject being treated clearly and concisely, and, though covering considerable ground, it is limited principally to such information as will be of every-day use to the practical electrician. Although written for electricians, the subject is treated in such a way that it may be readily understood by any one not familiar with the subject, while, at the same time, it contains some matter that may be of considerable interest and use to experienced electricians.

The first lecture is devoted to a description of the principles and laws of magnetism. It includes a clear explanation of how magnetism may be measured in units, this unit being a small force, 1,000,000 of which are equivalent to about two and one-quarter pounds. He shows how this unit may be represented by lines of force, each line representing one unit, and that therefore intensity of a magnetic field is the number of such lines per square inch or centimetre; that the "pull" in pounds in a magnetic field of known strength may readily be calculated.

He describes the important terms permeability, susceptibility, magnetic induction and resistance, as follows: in speaking of a piece of iron in a magnetic field, he says: "Lines of force find a more easy passage through the iron than through the air. On account of this behavior the iron is said to have a greater permeability than air, or greater conductibility for lines of force, or less magnetic resistance. The soft iron is said to acquire magnetism by induction, whilst it is in the field. The intensity of this induced magnetism divided by the strength of the field is called its magnetic susceptibility. The number of lines of force passing through one square centimetre of cross-section of the iron is called the magnetic induction. We have then two relations:

Intensity of magnetism = susceptibility × field strength;
Induction = permeability × field strength."

"The most simple way to regard the 'susceptibility' and 'permeability' of iron or steel is to consider these quantities as numbers, by which we must multiply the magnetizing field in order to obtain the intensity of magnetization, and the number of lines of force per square centimetre through the iron respectively, provided this be in the form of a long, thin bar, placed along the lines of force in the field." He gives the following figures: "From experiment

it appears that the greatest number of lines of force which a long bar of soft annealed iron, one square centimetre in cross-section can hold, is about 18,000 C. G. S. units. This induction bestows on it a maximum magnetization of 1,400 C. G. S. units."

In lecture II, is given a clear description of the magnetic effects of electrical currents, including Oersted's, Ampère's and Faraday's experiments, the galvanometer and the induction between currents and magnets. The following practical rule is given for determining the direction of the current by the direction of the lines of force, that is, by a compass needle: "Suppose a watch strung on the wire so that the current goes in at its face and comes out at its back, then the direction of the lines of force is in the direction in which the hands rotate." The generation of currents by cutting lines of force is clearly and briefly explained, both for the ordinary and the unipolar machines. The practical rule which he gives for finding the direction of the current induced, is well worth remembering, and is original with the author: if the thumb, fore- and middle-finger of the right hand, be held at right angles with one another, the middle-finger will point in the direction of the current if the thumb points in the direction of motion of the wire, and the fore-finger in the direction of the lines of force, considered as emanating from the north pole. He shows how the electro-motive force induced may be calculated, as one volt is generated when a wire cuts lines of force at the rate of 100,000,000 per second. It is also described how the ampère is determined from the magnetic effects. The self-induction of a current is compared to inertia, as of a heavy fly-wheel, which cannot be started or stopped suddenly without evidence of its inertia. This increased E. M. F. is compared to the sudden increased pressure in the hydraulic ram, or to that which causes the bursting of a water-pipe at a sudden closing of the stop-cock.

Lecture III, treats of electro-magnetism and the suction of a core into a solenoid. Weber's theory of the magnetism of molecules is illustrated with a glass tube filled with fine steel filings, which represent the molecules. The effect of permanent magnetic "set" of the molecules in steel as distinguished from soft iron, is compared to the permanent set in the torsion of a lead-wire as distinguished from a brass wire. In conclusion, he describes a method for measuring the intensity of a magnetic-field in dynamos.

In Lecture IV, are described various forms of magnets for different purposes. In speaking of magnetism, he says: "In the best dynamos, as now designed, the number of lines of force is about 6,000 to 10,000 per square centimetre." It is not stated, however, whether this is the magnetism in the core, or in the field, of the armature. We presume he means the former, as it then agrees with that found by actual experiment in some Edison and Weston machines. In reference to cast- and wrought-iron, he notes an experiment of Kapp, with two exactly similar machines, differing only in the iron. He found that the exciting current had to be more than doubled to generate the same E. M. F. with the cast-iron magnets; and with the same exciting current, the E. M. F. was eighty and 100 volts for cast and wrought-iron respectively. The lecture concludes with a description of secondary induction-coils and their application in practice, to systems of distribution, commonly known

as the Gaulard & Gibbs (owned in this country by Westinghouse), the Zipernowski-Deri, and others. In speaking of the sparking, jumping or striking distance, he says that 1,000 volts will discharge across ·005 inch between points, and that, generally speaking, the striking distance varies as the square of the E. M. F.

In Lecture V, the author gives a very complete *résumé* of the subject of units of measurements, both absolute and practical. Regarding the ordinary British system of weights and measures, he remarks that: "They seem to comply with the condition of creating the utmost possible waste of brain-labor in performing the simplest calculation." He compares the E. M. F. to differences of level, or head of water, expressed in feet, or what he terms the water motive-force. In discussing resistance, it is shown what is meant by resistance being a velocity. The lecture concludes with a summary of the units and their values, in a practical form. Among a few other units, not usually found in tables, is the following: "One *gauss* is strength of field in which a length of 1,000,000 centimetres of wire moving across the lines with a unit velocity, develops one volt E. M. F. = 100 times strength of one C. G. S. field. Strongest dynamo field is about 100 gausses." This unit, therefore, represents the intensity of a field having 100 lines of force per square centimetre, or about 650· per square inch. From the FRANKLIN INSTITUTE tests of dynamos, it appears that the field-intensity of the Edison and Weston machines was about forty to twenty-seven gausses.

Lecture VI, treats of practical measuring instruments. He very appropriately calls the voltmeter a coulomb-meter, a name which was suggested in this country some years ago, and which ought to replace the old term, as it is more appropriate and cannot be confounded with the term voltmeter. For the copper voltmeter, he recommends an addition of about five per cent. of sulphuric acid to the strong solution of sulphate of copper; density of current at least two square inches per ampère, if only one side of the plate is used; weigh only that plate which has the deposit; gain of weight in grams divided by ·00032709, gives the quantity in coulombs. This last figure does not agree very well with the determination of Kohlrausch, made in 1884, which is ·0003281. In discussing single coil galvanometers, he gives the following practical rule: The current in ampères is equal to $\frac{35}{22} \times$ radius of circle in centimetres $\times$ strength of magnetic field at its centre in C. G. S. units. By the latter is meant the number of lines of force per square centimetre. This is followed by a clear and simple description of the principles of the tangent galvanometer and its calibration, without the use of formulæ or trigonometric functions. The lecture concludes with the description of some of the practical ampère- and voltmeters, with the principles governing them. In using the electro-dynamometer for alternating currents, he states that, in certain cases, the real value is ten per cent. less than that indicated.

In Lecture VII, he makes a very good analogy between the fall of potential in a circuit and the fall of pressure in a water-main. This is followed by discussions of voltmeters, the most interesting of which is that of the potentiometer, a simple and effective instrument for measuring accurately potential and current, even very large currents.

In the discussion of resistance coils, he gives some useful figures regarding the size of wire to be used. To measure low resistances, as that of armatures, he recommends sending a weak, constant, battery current, through the armature, and an accurately determined resistance of ·01 ohm in series with it; touching the terminals of a high resistance galvanometer to both of the two terminals of each successively, then the deflections will be proportional to the resistances. In speaking of iron for voltmeters, he says: "A short, squat piece of iron has, so to speak, no magnetic memory. Its past magnetic history is immediately obliterated when placed in a new magnetic field."

In Lecture VIII, he mentions that storage batteries do not store electricity, but energy. A very good description of primary and secondary batteries, polarization and standard cells, is given. He says that the E. M. F. of a battery, in volts, multiplied by 988,960, gives the greatest theoretical amount of energy in foot-pounds, which can be produced per pound of zinc in that battery. With a motor, Joule showed that only one-seventh of this was obtainable in practice. In storage batteries, made of lead grids filled with the oxide, he says the proper charging current is about two ampères per square foot of negative plate, including the surfaces on both sides of the plate; for discharging, about three ampères per square foot. These cells give about 25,000 to 35,000 foot-pounds per pound of plates reckoning both positive and negative together; in the Planté type only 12,000.

In Lecture IX, in describing motors, he says that Joule obtained with a Grove battery 331,400 foot-pounds per pound of zinc, while a pound of coal costing but one-thirty-sixth as much, yields 1,000,000 foot-pounds by means of the steam-engine. This lecture includes dynamos and motors, which are briefly described, and concludes with an interesting description of Hopkinson's experiments on the efficiency of dynamos and motors in the transmission of power.

In the Appendix, on the lifting-power of electro-magnets, Mr. Shelford Bidwell endeavors to show that Rowland is wrong in his statement that the greatest lifting-power was 177 pounds per square-inch. He claims that it is much greater than this.

Of errors in the book, we notice the following:

Page 13, third line "use" should evidently be "rise."

Page 21, the letters "n. s." on the little test magnets in the lower part of the figure should be reversed.

Page 23, the letters "N. S." on the horizontal solenoid should be reversed.

Page 26, eleventh line "*Fig. 14*" should read "*Fig. 15*."

Page 41, twelfth line from bottom, 3·14 should evidently be 6·28, as this is the circumference of a circle of two cm. diameter.

Page 45, tenth line, "force" should be "form."

Page 91, second and fourth lines from bottom, 3·1415 should be 6·2832.

Page 120, fifth line from bottom, "use" should evidently be "rise."

Page 121, twelfth line from bottom, "hydrostatic" should evidently be "hydrodynamic," as the former refers to water at rest.

Page 125, the first asterisk should be omitted.

Page 172, the formula might be more appropriately written $\frac{2x}{746}$, or $\frac{x}{373}$, as this is much simpler, and at the same time shows how it is deduced. On the same line, "372" should be "373." C. H.

THE THEORY AND PRACTICE OF SURVEYING. By J. B. Johnson, C. E. New York: John Wiley & Sons.

This volume of Prof. Johnson is far ahead of most treatises on surveying with which we are acquainted. There is plenty of room for improvement in this art among us. We have practised it rudely, and our text-books heretofore have been designed to meet a resulting state of things. We say rudely, where others might say with simplicity, for simplicity and rudeness are usually synonymous terms in the arts. In reality, no such quality as simplicity is in existence.

Prof. Johnson has divided his treatise into the various kinds of surveying generally practised. On land or farm surveying he says little, if anything, new, but describles fully and briefly the important points of this narrow subject. He omits those useless problems on the division of land, which encumber some other works. He treats next of topographical surveying by the transit and stadia, a method already old in Europe, but little known and less practised among us outside of Government topographical parties. It is not better than any other method; the plane table is not superseded; neither the transit, level and clinometer method; it is simply tinted, in certain cases, to give the most quickly-accurate results.

The subject of railroad surveying, we are sorry to see treated so shortly; only ten pages being devoted to it, without the aid of any illustrated examples of actual practice. The author suggests the application of the transit and stadia method to railroad work, and undoubtedly it would often prove advantageous; but we do not agree with him that its usefulness can be extended so far as to dispense with *measured* bases for the *main* preliminary lines. Hydrographic surveying is well handled. The instruction relating to it is founded upon Government practice. It includes the gauging of streams, a subject which, we must confess, we are surprised to see associated with the art of surveying.

The chapter on mining surveying has been written by Mr. A. Russell, of Colorado, and to the best of our ability to judge, appears to merit praise. It details the method of procedure in vogue in the far West. We should have been pleased to see this chapter augmented by a description of French and German practice, for in France and Germany the mines are very accurately surveyed.

The following chapter, on "City Surveying," was written by Mr. Bouton, City Surveyor of St. Louis, Mo. While an interesting chapter, it is founded exclusively on what appears to be Western practice. By combining the substance of this chapter with the instruction obtainable from the practises of such cities as Philadelphia, New York and Boston, and by illustrating the whole with some examples of city plans, we might have had a *very* valuable chapter.

Triangulation and geodetic operations are the author's strong points. He introduces the student into these subjects in an able manner; and we would advise the student to master their principles. We are upon the threshold of entering into the practice of triangulation for all accurate work, whether for line or area, following simply what has long since occurred in Europe, and will naturally take place as population becomes somewhat dense.

We might say much more upon this volume, all the contents of which we have not the space to notice, although we have read the work from beginning to end, and were altogether well pleased with it. E.

MECHANICS OF THE GIRDER. By John Davenport Crehore, C.E. New York: John Wiley & Sons.

Nearly 600 octavo pages are devoted to the calculation of bridges and roofs in this volume. Yet the mathematics employed are not difficult; the formulæ are followed in most cases by examples; the arrangement of the contents is neat and careful; the type is clear. No space is wasted in useless mathematical investigations, and everything discussed is applicable in practice. The mechanics of the girder, for all the various shapes that it assumes before the engineer, seem to have received here thorough and elegant treatment. Considerable time and conscientious work have evidently been directed toward this end.

The last chapter treats of the calculation of the weights of bridges from the strains. This is a comparatively new field of investigation. More than thirteen years ago, we deduced, to guide our practice, complete formulæ from the strains for the weight of trussed girders with parallel flanges, whatever the system of bracing, before we saw anything of value in print relating to the subject. A certain ratio, liable to little change, is required between the theoretical and actual weights of the girder, due to the extra material in connections. E.

THE CIVIL ENGINEER'S FIELD BOOK. By Edward Butts. New York: John Wiley & Sons. 1886.

The author tells us in his preface that the design of his book is to show us how to economize time and trouble in laying out railway curves. But, he illustrates his formulæ by examples, which, inconsistently with the aforesaid design, are solved by long multiplications and divisions, instead of by logarithms to five places. No well meant labor, however, is without some good attached to it. The greater portion of this little volume is devoted to an extensive table of tangent and curve-lengths for all angles of intersection from 0° to 90°, so that, if an engineer will confine himself as much as possible to whole-degree curves, such as 1°, 2°, 3°, etc., up to 10° inclusive, the table spares him the calculation of the lengths of his tangents and curve. As an example of our meaning, suppose that his angle of intersection measures 43° 21′, and that he intends to use a 2° curve; then by the table 1141·55 feet is the length of his tangents, and 2172·50 feet that of the curve, measured by 100-foot chords. E.

THE SURVEYOR'S GUIDE. By B. F. Dorr. New York: D. Van Nostrand. 1886.

How this little pocket-book came to be published by an Eastern house is a mystery. It is addressed especially to surveyors engaged on the section lands laid out by the United States Government in the West. Quite elementary in character, it is adapted to the wants of the least informed persons capable of undertaking the duties of a section surveyor. E.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 15, 1886.*]

HALL OF THE INSTITUTE, December 15, 1886.

CHAS. H. BANES, President, in the Chair.

Present, sixty-seven members.

Additions to membership since last meeting, eleven.

The Special Committee to "Formulate a Plan for a State Weather Service" presented a report, which appears in this impression of the JOURNAL. The report was adopted, and the committee was continued, with directions to carry the plan into effect.

The La Cour-Delany Committee reported progress.

The following nominations for officers were made, viz.:

For *President* (to serve one year), ... JOSEPH M. WILSON.
For *Vice-President* (to serve three years), ... CHAS. BULLOCK.
For *Secretary* (to serve one year), ... WM. H. WAHL.
For *Treasurer* (to serve one year), ... SAMUEL SARTAIN.
For *Auditor* (to serve three years), ... WM. B. COOPER.

For *Managers* (to serve three years):

CHAS. H. BANES,	WASHINGTON JONES,	A. E. OUTERBRIDGE, JR.,
C. CHABOT,	EDWARD LONGSTRETH,	THEO. D. RAND,
WM. H. GREENE,	ISAAC NORRIS, JR.,	COLEMAN SELLERS.

Nominations were then made for members of the Committee on Science and the Arts.

Dr. W. G. A. BONWILL, of Philadelphia, exhibited specimens of pure gold condensed under the blows of the electro-magnetic mallet and the mechanical mallet, and made some remarks upon the same.

The Secretary's Report was made, followed by some remarks by Prof. E. J. Houston, on "The Climatic Effects of the Removal of Forests."

The Secretary presented, on behalf of Mrs. O. H. WILLARD, of Philadelphia, a portrait of Daguérre, painted by the late Abraham Woodside. The gift was accepted, and a vote of thanks was passed to the giver.

Adjourned. WM. H. WAHL, *Secretary.*

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS.

ELECTRIC BREVITIES.—As the English electricians occasionally publish articles of interest about storage batteries, it may be well to call the attention of American readers to the fact that what the English call positive and negative regarding the cell, is just the reverse of what we call them. They refer to the plates and we to the poles; both, of course, are correct. They are apparently more concerned with what takes place in the cell, while we are more interested in what the cell does in the external circuit, similarly to a dynamo, in which the Englishman's designation of positive and negative would be very confusing, to say the least. The positive pole is that attached to the negative or peroxide plate.

Advocates of wrought-iron for dynamos sometimes make some very misleading statements. In the report about an experiment with two machines of the same size, differing only in the cast- and wrought-iron in the magnets, the wrought-iron advocate says, that to generate the same number of volts the exciting current had to be more than doubled for the cast-iron magnets. This naturally leads one to suppose that cast-iron is far inferior. In another experiment, however, with the same machines, the E. M. F. was eighty and 100 volts respectively, with the same exciting current. This agrees with other data published by others, and shows in favor of cast-iron, if the price is considered. It also shows that in the first experiment the cast-iron was highly over-saturated, and that, therefore, the results of that test have no practical value for a comparison.

We are informed that an American engineer, who is an advocate of alternating currents, claims that he can charge storage batteries in the alternating current circuit. Until he can conclusively demonstrate that this can be accomplished in practice, as distinguished from a drawing or a laboratory experiment, we are justified in guarding persons against believing that the alternating current does not fail in this respect in practice. That it may be accomplished by the aid of an alternating-current motor driving a continuous-current dynamo is not new, but we presume that this is not what was meant.

Some years ago, it was remarked, jokingly, that in course of time we would be able to telephone or telegraph without the use of a wire joining the two places. Although this, at first thought, might appear impossible, yet it has actually been accomplished by a very ingenious method, invented by Prof. A. E. Dolbear. Although he described it as early as 1883, the recent issue of the patent (October 5th) brings it again before our notice. He describes it briefly as follows, in the November number of the *Electrical Engineer*: "The idea is to cause a series of electrical discharges into the earth at a given place without discharging into the earth the other terminal of the battery or induction coil. A feat which I have been told so many, many

times was impossible but which can certainly be done. An induction coil isn't amenable to Ohm's law always! Suppose that at one place there be apparatus for discharging the *positive* pole of the induction coil into the ground, say 100 times per second, then the ground will be raised to a certain potential 100 times per second. At another point let a similar apparatus discharge the *negative* pole 100 times per second, then between these two places there will be a greater difference of potential than in other directions, and a series of earth currents, 100 per second will flow from the one to the other. Any sensitive electrical device, a galvanometer or telephone, will be disturbed at the latter station by these currents, and any intermittance of them, as can be brought about by a Morse key, in the first place, will be seen or heard in the second place. The stronger the discharge that can be thus produced, the stronger will the earth currents be of course, and an insulated tin roof, is an excellent terminal for such a purpose. I have generally used my static telephone receiver in my experiments, though the magneto will answer." In conclusion, he adds that it is adapted to telegraphing between vessels at sea.

There has been considerable in both daily and technical papers lately about the system of distribution known as the Gaulard & Gibbs, in which alternating currents of high tension (!) are "converted" by an apparatus like a Rhumkorff coil into low tension currents for incandescent lighting, for which system a great saving of copper is effected. It is not very creditable to the Americans to bring before the public as new a system which has been known and used in Europe for a number of years past. If this system "revolutionizes electric lighting," it has certainly had a chance to prove its great advantages by this time. We are informed by an English electrician that the only installation in London of this system has been abandoned, and is to be replaced by another. One of the difficulties seems to be in the intense heating of the iron parts of the converters. We are told that three laboratories have been set on fire by this, in the experience of one electrician. In order to be self-regulating, the converters, it is said, have to be placed in multiple arc, and not in series, thus reducing its advantages. In this connection, it may be interesting to note that Alexander Bernstein, who, as is well known, is an American, applied for a patent for this system as early as January, 1883, which was rejected on the ground that "it is not apparent how applicant in any case can get more quantity from a secondary coil than he has in the primary." It certainly is not apparent how the Patent Office is justified in granting a patent for this same invention, in 1886, to Gaulard & Gibbs after refusing it to Bernstein. There is something wrong somewhere, and it certainly is not due to any difference in the action of the induction coil now and then.

Certain English electricians seem to be either astonishingly ignorant of what is being done in this country, or else intentionally overlook it, when they say that "at the present moment the most perfect incandescent light dynamos are produced in England. As regards arc lighters, we are in fairness bound to admit the superiority of American designs; but for incandescent lighting and for motive-power purposes we claim the lead." Then follows a statement by R. E. Crompton, showing that his machine and that

of Hopkinson (Edison remodelled) have an electrical efficiency of ninety-six per cent., which is reduced to the somewhat high inductor-velocity of fifty feet per second. If he had referred to the FRANKLIN INSTITUTE tests, he would have found that an American machine had an efficiency of 96·9 per cent. at the *lower* inductor-velocity of forty-five feet per second. Not only this, but the induction was 1·69 volts per foot in the latter at a speed of forty-eight feet per second, while those of the former were only ·66 and ·48 volts per foot at a higher speed. Even if the whole of the armature-wire is taken into consideration; that is, both the active and the inactive, our American machine still gives ·725 volts per foot at the lower speed, or ·755 at fifty feet per second. Thus, in both qualities the American incandescent light machine excels. A French machine—Raffard-Breguet, of the Gramme type—was reported to have an efficiency of seventy-eight per cent. and an induction of only ·106 volts per foot at fifty feet per second, while the current density was astonishingly high—9,240 ampères per square inch in the armature.

In a recently-published advertisement, the inventor of a motor claims as a particular advantage of his motor, that he has succeeded in diminishing the objectionable counter electro-motive force! We presume he was not joking, but it nevertheless afforded electricians amusement. We refer him to some elementary works on the subject, and for the benefit of others, we call attention to the fact that as the work consumed by a motor is C E; that is, the current × potential, and that part of this is consumed in the resistance, and is lost as heat, while the rest, represented by the current × counter E. M. F. is converted into mechanical work; therefore, the *greater* the latter the *better* the motor. C. H.

EFFECTS OF THE DESTRUCTION OF THE FORESTS.—The recent meeting of the Forestry Association in Philadelphia again calls public attention to the necessity for the enacting of laws for the better protection of our forests, and for renewal in case of their accidental or enforced removal.

The grave importance of the subject we believe will warrant the following brief *résumé* of the effects produced by the removal of the forests from a comparatively extended area. We will view these effects from the stand-point of geographical physics.

The axe of the pioneer, often taken as the symbol of a progressive civilization, unless intelligently employed, more frequently proves a bane than a blessing. The indiscriminate removal of the forests from any country necessarily produces a train of evil results both far-reaching and enduring. And yet the forest is the home of civilization, and must, therefore, make way for man.

What intelligent forestry laws should endeavor to accomplish is to ensure the continuance of certain forest areas, to prevent the indiscriminate and unnecessary removal of the trees, to avoid devastation by fires, and to provide for the replanting of areas either purposely or accidentally stripped of their forest growth.

The evil effects resulting from the removal of the forest from comparatively extended areas may be conveniently grouped under two heads, viz:

(1.) The effects produced by the removal of the vegetable covering from such areas; and

(2.) The effects produced by the subsequent removal of the soil itself by the action of water on the bare earth.

The evil effects caused by the removal of the vegetable covering from any section of country may be arranged under two general heads, viz.: First, Climatic changes; and second, Changes in the distribution of the precipitation.

(1.) *Climatic Changes.*—The bare, unprotected earth, no longer shielded by its vegetable covering, both heats and cools rapidly. There thus result great extremes of temperature. The air over the denuded area is intensely hot in summer, and very cold in winter. The soil is baked and parched in summer, and frozen to a much greater depth and at an earlier date in winter.

When such area is of sufficient extent, the climatic changes thus caused cannot fail to be marked and far-reaching.

(2.) *Changes in the Distribution of the Precipitation.*—When the forests are removed, the rain instead of sinking deep into the ground, and filling the reservoirs of springs, drains rapidly off the surface into the river channels, thus increasing the frequency and severity of inundations. When the ground is covered with trees or other vegetation, the rain sinks quietly into the earth along the trunks or stems, or is retarded by the undergrowth for a sufficient length of time to permit it to sink directly into the earth.

Rapid surface drainage and consequent inundations are especially apt to occur in the early spring, when the ice and snow melt along the river courses. This is due to the fact that if the first snow of the season should occur after the first severe frost, which is nearly always the case, it falls on the bare, unprotected, and consequently deeply-frozen ground. On melting in early spring, it cannot sink into the still frozen earth, and therefore drains rapidly off the surface. When, on the contrary, the forest still remains, the winter's first snow falls generally on the unfrozen earth and keeps it from freezing thereafter.

The rapid surface drainage thus effected by the destruction of the forest brings a train of evil effects, both on the uplands and the lowlands. The water drained directly into river channels not only brings disastrous inundations to the low-lands, but being lost to the reservoirs of the upland springs, causes them either to dry up, or to become limited in their discharge on the first approach of drought. The surplusage of water that occurs during the inundations of the rivers is necessarily followed by a marked deficit during even comparatively dry weather. The rain-fall, instead of reaching the rivers indirectly, through the discharge of springs, in perhaps several weeks, is rapidly drained therein, directly, in a few days.

It is this circumstance which has most probably led to the popular belief that the destruction of the forests produces a direct influence on the amount and frequency of the rain-fall in the denuded districts. Though it cannot be denied that the removal of the forests from a very extented area, must to some extent influence the rain-fall of the country, yet it is evident that

such influence is rather that above pointed out; viz., an effect on the distribution of the rain-fall in its time of drainage into the river channels, rather than on the distribution in point of either frequency or quantity.

Let us now consider the nature of the effects produced by the removal of the soil from the uncovered earth, consequent on the rapid drainage of its surface.

The vegetable mould, or soil of any section of country, is a result of gradual accumulation or formation, not only by the disintegration of the primitive rocks or earth, but also by its continuous enrichment from the gradual decay of pre-existing races of plants. Given the climatic conditions of light, heat and moisture, a soil will gradually be evolved, even from bare rock, but its evolution is a matter of comparatively extended time. It is therefore an almost fatal loss to the uplands, to have them denuded more or less completely of their virgin soil, by the rapid surface drainage that necessarily follows the indiscriminate removal of the forests.

The evil, however, does not stop here ; not only are uplands impoverished by the removal of their virgin soil, but the silt, thrown into the river channels, accumulates in sand-bars, or flats in the channels, or in the mouths of rivers, thus proving a serious impediment to inland navigation ; or, spread over the alluvial flats in the lower courses of the river, brings contagion and death to the adjoining districts.

Besides the evils above pointed out, which, as will be seen affect nearly all parts of the river basin, the uplands as well as the lowlands, there are two other evils that have not as yet been generally recognized, viz.: hail-storms and tornadoes.

There can be but little doubt that the sudden and extreme changes of temperature that are caused by the removal of the forests over extended areas, produce meteorological conditions, favorable to the existence of hail-storms and tornadoes. That both of these destructive meteors are especially prevalent in the neighborhood of districts from which the forests have been removed, statistics will show ; neither can occur without great differences of temperature, and such differences are the necessary concomitants of denuded areas.

The necessity for intelligent legislation for the better protection of the forests is apparent. We trust therefore that the the American Forestry Association will continue in their good work. E. J. H.

Bulletin of the United States Geological Survey, No. 31.—Mineral Springs of the United States.—Dr. Albert C. Peale, of the United States Geological Survey, has made an admirable compilation of the mineral springs of the United States, that, besides being of value to the geological world, cannot fail to prove of considerable interest to the medical profession.

In this publication of the *United States Geological Survey*, Dr. Peale has made a very complete classification of nearly all the known mineral springs of the United States. The springs are arranged in the following groups, viz: The Northern Atlantic States, the Southern Altantic States, the Southern Central States, the Northern Central States, and the Western States and Territories.

Besides a general description of the more noted mineral springs, there are given reliable chemical analyses of the various waters. This feature cannot fail to be of value to the medical profession.

The completeness of the classification may be judged from the fact that it includes some 2,822 localities.

Speaking of the definition to be attached to the word "mineral water," the author justly remarks that such definition must necessarily vary according as to whether the subject be viewed from the standpoint of the geologist, or from that of the physician. On the one hand, water is itself a mineral, and is seldom found absolutely pure in its natural state. On the other hand, from a therapeutic standpoint, any water that has an effect on the animal body, from the mineral substances it contains, is a mineral water, no matter how small the percentage of such mineral matter. Generally speaking, however, mineral waters are such as are characterized by an unusual proportion of mineral matter, or whose temperature is considerably above the normal, in which case the percentage of mineral ingredients is almost necessarily high.

Without going into a special classification of mineral waters, the author gives the following general divisions:

(1.) As regards their temperature as thermal or non-thermal.

(2.) As regards the presence of certain dissolved gaseous substances, as carbonated, sulphuretted, or carburetted, etc., waters.

(3.) As regards the mineral ingredients proper, as chalybeate, alkaline, saline, calcic, silicious, or acid, named from the predominant or characteristic solid constituents.

The book is furnished with a valuable, because unusually complete, index of the various localities. E. J. H.

Application of Electricity to Weaving.—A manufacturer of Roubaix, M. Henry Buisini, has just discovered a very curious application of electricity to looms. He adopts an indicator which strikes when a thread in the warp breaks, and thus saves the warper from taking out any of his work to find the flaw, and he need not pay such close attention to the quickly moving threads which is so injurious to the sight. The invention can be applied to power-looms.—*Chron. Industr., Sept. 19, 1886.* C.

CHEMISTRY.

On the Vapor-Pressures of Bromide and Iodine, and on Iodine-monochloride. By W. Ramsay and S. Young (*Jour. Chem. Soc.* **49**, 453)—The authors have here applied the results of their numerous observations upon vapor-pressures, to the determination of the melting-points of bromine and iodine, and also of the boiling-point of bromine. The method employed is that described by the authors (*Jour. Chem. Soc.* **47**, 42). Every precaution was taken to insure the purity of the substances. In the case of bromine, as well as of iodine, the curve expressing the relation of pressure to temperature for the solid substance is not a continuation of that for the liquid, but they intersect. For bromine, the curves intersect in a point corresponding to a temperature of 7°·1 and a

pressure of 44·5 mm.; while in the case of iodine, the curves intersect at 114°·3 and pressure 91 mm. It has been proved by the authors that for a number of substances the point of intersection of these two curves corresponds to the melting-point. From the combined data, of direct observation, of the intersections of the vapor-pressure curves, and of the intersection of the lines for the ratios of the absolute temperatures at constant pressure of bromine to water, of iodine to water, and of bromine to iodine, that the correct values for the melting-points are: bromine, — 7°·05; iodine, 114°·15. Boiling-point of bromine, 58°·7, which agrees closely with previous observations. A. G. P.

SARDINE OIL.—Two years ago a substance of the consistency of butter, and of an insupportable odor, was introduced from Japan into Europe. It was made from a particular kind of sardines and contained twenty-five per cent. of solid, fatty matter to seventy-five per cent. liquid oil. This oil is now refined at Yokohama and exported in three grades, the coarsest being known as fish-tallow or fish-stearine. Its production is also enormous in Cambodia, Tonquin, Annam and Cochin, China. M. Villon, of Lyons, has analyzed sardine fat and finds that it contains:

Water,	5·52
Oleine,	57·18
Margarine and stearine,	35·11
Free oleic acid,	1·50
Iodine,	0·1
Organic remains,	0·2
	99·61

The industrial applications of this new product are only in an experimental stage, but M. Villon thinks that pure or in combination it may render great service to leather dressers and to soap and stearine workers. It can also be used in lubrication.—*Chron. Industr., Sept. 19, 1886.* C.

FUSTIN, OR THE GLUCOSIDE OF FISETIN.—This compound is prepared from the above fustin tannide by treatment with acetic acid and crystallizing from hot water. It occurs in yellowish-white, silvery needles, melting at 200°, and dissolving easily in warm water, alcohol and dilute alkalies, but sparingly soluble in ether. H. T.

ON ESSENTIAL-OILS. PART III. THEIR SPECIFIC, REFRACTIVE AND DISPERSIVE ENERGY. By J. H. Gladstone (*Jour. Chem. Soc.*, **49**, 609).—In this paper, the author brings forward the arguments founded on the phenomena of dispersion and refraction, which throw light upon the question as to the number of doubly-linked carbon-atoms present in those hydro-carbons known as essential-oils. The following definitions are given: The specific refractive energy of a substance is its refractive index minus unity divided by its density, and, calculated for the line A of the solar spectrum, is represented by the formula, $\frac{\mu A - 1}{d}$. The specific dispersive energy is the difference between the specific refractive energies of the two extreme visible lines A and H; *i. e.*, $\frac{\mu H - \mu A}{d}$. The foregoing expressions multiplied by

the atomic weight, give what are termed, respectively, the refraction and dispersion equivalents; *i. e.*, $P\frac{\mu_A - 1}{d}$, and $P\frac{\mu_H - \mu_A}{d}$. In all saturated compounds, the refraction equivalent of one atom of carbon is found to be 5·0 for the line *A*, and that of hydrogen 1·3. It has long been known that more than thirty of the essential-oils which have been examined, give refraction equivalents a little above the theory. Subsequently, Brühl showed that in case of "double-linkage," each such carbon-atom has a refraction equivalent about 6·1, or, each pair increases the normal equivalent about 2·2.

Among saturated organic compounds, the author has found the dispersion equivalent of CH_2 to be 0·342. The "double-linkage" of a pair of carbon-atoms tends to increase the dispersion equivalent.

The main results of the investigation will be found in the following table. That theory is expressed in Column 4, which contains the number of pairs of carbon-atoms taken to be "double-linked," on the basis of each substance containing ten atoms of carbon. Whether, in fact, it is C_{10}, or C_{15}, or C_5, is not indicated by these optical properties.

Hydrocarbon.	Experimental.			Theoretical.	
	Specific Refractive Energy.	Specific Dispersive Energy.	Pairs of C Doubly-Linked.	Specific Refractive Energy.	Specific Dispersive Energy.
Cymhydrene,	0·543	0·0246	None.	0·543	0·0243
Menthene,	0·548	0·0313	1	0·547	0·0298
The terpenes,	0·537	0·0295	1	0·537	0·0296
Terebathene,	0·537	0·0294	1	0·537	0·0296
Camphene,	0·528	0·0269	1	0·537	0·0296
The cedrenes,	0·538	0·0296	1	0·537	0·0296
The citrenes,	0·551	0·0334	2	0·553	0·0354
Isoterebenthene,	0·552	0·0337	2	0·553	0·0354
Caoutchene,	0·554	0·0366	2	0·553	0·0354
Cymene,	0·560	0·0406	3	0·558	0·0413
Isoprene,	0·592	0·0470	4	0·585	0·0472

A. G. P.

Separation and Properties of Germanium.—C. Winkler has published (*Journ. für Prakt. Chemie.*, **34,** page 177,) the following as the best method for the separation of germanium. Finely-powdered argyrodite is fused with a mixture of equal parts of sulphur and sodium hydroxide at a dull red heat in a Hessian crucible. The pasty mass is poured into a heated iron mortar and pulverized after cooling; the powder is exhausted with boiling water, and the residue is again fused with sulphur and sodium hydroxide. The solution obtained is exactly neutralized with sulphuric acid and allowed to stand twenty-four hours, in which time sulphur deposits, carrying with it the sulphides of arsenic and antimony, while the germanium remains dissolved in the opalescent liquid. This liquid is decanted, mixed with an

excess of hydrochloric acid, and saturated with hydrogen sulphide. In the course of a day, a voluminous white precipitate of germanium sulphide separates; this is washed with water saturated with hydrogen sulphide, and containing one-fourth its volume of hydrochloric acid, and the washing is concluded with ninety per cent. alcohol saturated with hydrogen sulphide.

The germanium sulphide so obtained is roasted at a low temperature and then heated with nitric acid. On calcining the residue, an oxide is formed that may be reduced in a current of hydrogen, and the pulverulent germanium thus produced is sufficiently pure to serve for the preparation of its compounds.

The best flux for fusing the element, which melts at about 900° C., is borax, and by slowly cooling the molten mass the germanium may be obtained in fine, regular octohedra, having a bright metallic lustre and a grayish color.

The density of germanium at 20°·4 C. is 5·469. Its atomic weight, determined by analysis of the chloride, G_2Cl_4, is 72·32. It is not attacked by hydrochloric acid. Nitric acid and nitro-hydrochloric acid convert it into a white oxide. By the aid of heat, sulphuric acid converts it into a soluble sulphate. It forms explosive mixtures with the chlorates and nitrates.

W. H. G.

THE MOST RATIONAL DIVISION OF A SET OF WEIGHTS.—J. D. Van de Plaats (*Receuil des Travaux Chimiques des Pays Bas*, **5**, 215), gives the results of calculations as to the best set of weights for the various uses of a chemist. The two principal objects of weights are (A) the determination of the mass of any given substance; (B) the separation of a given mass of any substance. The requirements of a set of weights are: (1.) That the number of weights be as small as possible; (2) that the operations A and B may be performed in the least possible time; (3) that the different weights may be placed on the same pan of the balance; besides this, it is desirable (4) that the weights may be readily comparable among themselves; (5) that there shall not be two weights of the same value. As a general conclusion, the author considers that the most desirable weights for a chemist would be of values in the system 1, 2, 3, 5. W. H. G.

ON THE PREPARATION OF FORMALDEHYDE.—B. Tollins (*Berliner Berichte*, **19**, 2135), publishes as the best method for the preparation of formaldehyde, the aspiration of air through methyl alcohol heated to 45°–50° C., in a water bath, then through a tube containing copper gauze heated to the softening point of Bohemian glass; the glass tube containing the gauze must be supported by wrappings of copper gauze or foil. In this manner a few litres of thirty or forty per cent. formaldehyde solution may be prepared in a short time, and hundreds of grammes of oxymethylene may be readily obtained.

W. H. G.

A NEW METHOD FOR OBTAINING THE SPECIFIC GRAVITY OF EASILY SOLUBLE SUBSTANCES.—L. Zehnder describes (*Ann. Phys. Chem.*, **29**, 249), a method which is equally applicable to insoluble substances. The pyknometer for solid substances is employed, and after the weight of the

instrument and solid has been found, the pyknometer is inverted in distilled water: the solid falls out, and is, of course, replaced by an equal volume of water, whose weight is then determined. Figures are given, showing that the method is trustworthy. **W. H. G.**

A Sure Method of Cutting Glass Tubes.—Ernest Beckmann (*loc. cit.* 530), states that glass tubes of any thickness and diameter, as well as funnels, bell-jars, etc., may be safely cut by making a file mark and then building up rings of wet filter paper, 1–2 mm. high, and 2–4 mm. wide on each side of the mark, at a distance of 1–2 mm. The intervening space is then heated in a Bunsen burner flame, or better, by the pointed flame of a blast-lamp, while the tube is rotated on its axis. The tube then separates at once in the line between the walls of filter paper. The paper must be saturated with water, must be evenly laid on, so that it builds up straight walls, and the thickness to which it is wrapped will depend upon the diameter and thickness of the tube. W. H. G.

Notes on Russian Petroleum.—Prof. C. Engler, of the Polytechnic School at Carlsruhe, Germany, has recently published (*Ding. Jour.*, **260**, pp. 337, *et seq.*) a lengthy account of a visit he paid to Baku and the Russian oil-fields in the fall of 1885, and taken the opportunity to collate much of historical and statistical interest with regard to this industry.

The first production of burning-oils from this field was about 1855, and strange to say was not from the naphtha or crude oils already abundantly found at that time, but was from a solid material resembling ozokerite, and known as "kirr." Application having been made to the great German chemist Liebig, he sent an assistant of his, Moldenhauer, who erected the first refinery and soon abandoned the "kirr," which yielded only fifteen to twenty per cent. of a heavy oil, and began the distillation of the crude naphtha. He left in 1860, and was succeeded by Eichler, who is still engaged in the work at Baku.

The production of crude oil for the last ten years, reckoned in barrels, for comparison with American production, is as follows:

	Barrels.		*Barrels.*
1876,	1,385,714	1881,	3,500,000
1877,	1,728,571	1882,	4,857,142
1878,	2,285,714	1883,	5,714,285
1879,	2,642,857	1884,	8,071,428
1880,	3,000,000	1885,	11,685,714

The price of the crude oil, which in 1872 was still $2.45 per barrel, dropped in 1877 to forty-two cents per barrel, and to-day ranges from fourteen to twenty-one cents per barrel.

The production of refined burning-oil in Baku for the year 1885 was 3,214,285 barrels, of lubricating-oil, 185,714 barrels, and of residues, 3,642,857 barrels.

It will be interesting to compare these figures with the present production and export of American petroleum. According to Stowell's *Petroleum Reporter*, the production of crude oil for the year 1885 was 20,776,165 barrels, and the amount of refined burning-oil exported to Europe was 11,428,571 barrels.

The flowing-wells of the Baku district, in the energy with which they throw out the oil and the quantity so projected, far exceed even our largest American "spouters." In 1883, three such powerful oil fountains were opened, viz.: the Lianozoff, the Drujba (pronounced Druschba), belonging to an American company, and the Nobel Brothers, No. 9. The Lianozoff, the first opened, threw a stream of oil 200 feet high, while the Drujba well gave a stream that at times rose to 300 feet, and yielded some 57,143 barrels of crude oil daily, an amount more than eight times that of the Armstrong Well, No. 2, struck in 1884, in Butler County, Pa., and considered the greatest flowing-well of the Pennsylvania oil-field. The Nobel Brothers No. 9 fully equalled the Drujba, and is said to have yielded 800,000 barrels of oil in four weeks' time.

The depth of these yielding wells is much less than those of the American oil-fields, the average depth of the wells, in 1885, being 482 feet.

The advent of the firm of Nobel Brothers, in 1875, gave a great impulse to the production, refining and handling of the petroleum of this district. They particularly improved the transportation and delivery methods for all the products, introduced pipe-lines, oil-tank cars and oil-tank steamers on the Volga and the Caspian Sea, and experimented upon the proper utilization of the large amounts of residues that remained, in the preparation of burning and lubricating-oils.

It is well-known that the Russian petroleum differs from the Pennsylvanian in its specific gravity, being distinctly higher in most cases. This is explained when we compare the distillation results. Thus, according to Engler, the following results are gotten with the oil from the two main localities:

	Balakhani.	*Bibieybat.*
Volatile-oils (benzene, etc.),	5 to 6 per cent.	10·5 per cent.
Illuminating-oil I (kerosene),	27 to 33 "	40 "
Illuminating-oil II (solar-oil),	5 to 6 "	13·5 "
Residues,	50 to 60 "	36 "

This shows a relatively small percentage of illuminating-oil as compared with the Pennsylvanian and other crude oils, as will be seen from the following table:

	Pennsylvanian.	*Galician.*	*Roumanian.*	*Alsacian*
Volatile-oils,	10 to 20 per cent.	3 to 6 per cent.	4 per cent.	. . . .
Illuminating-oil,	60 to 75 "	55 to 65 "	60 to 70 "	35 to 40 per cent.
Residues,	5 to 10 "	30 to 40 "	25 to 35 "	55 to 60 "

Of course, the residues from the Baku refineries can be made to yield most valuable lubricating-oils.

Interesting statements as to the character of the residues and as to methods of distillation, etc., will have to be deferred for another abstract.

S. P. S.

ON A LITTLE KNOWN CAUSE OF CORROSION OF STEAM GENERATORS. M. M. Klein and Berg, (*Comptes Rendus*, **102**, 1170.)—It often happens in sugar refineries, where syrups are evaporated in a vacuum by means of steam coils, that in consequence of defects in the apparatus some sugar is introduced into the boilers.

Whenever there is molasses containing acid products, especially butyric

acid, corrosion is naturally looked for, but it has been generally supposed that pure syrups are nearly or quite inoffensive. Experiments have been made with cane-sugar, grape-sugar, maltose, glycerine and mannite dissolved in water in known proportions. The solution of these different substances was heated in sealed tubes at a temperature of 115° to 120°, and the action upon iron determined in two ways: (1.) By inserting iron in the liquid; (2.) by the diminution in weight of the tubes themselves. For comparison in each experiment, iron tubes containing distilled water were heated, which gave no solution of iron, but simply insoluble sesqui-oxides more or less hydrated in small quantities. In every instance, the sweetened liquids which were heated in contact with iron, gave a marked acid reaction. The liquid took an amber color with a greenish tinge, contained a notable proportion of iron and held in suspension mica-like flakes, formed of a substance analogous to the ill-defined bodies which have been extracted from caramel, containing evident traces of iron. At the same time considerable hydrogen was set free. Other things being equal, the quantity of iron dissolved increases in proportion to the amount of sugar in the solution; the iron was in the form of acetate. Glycerine and mannite appeared to have no action upon the iron. Zinc is strongly attacked by sugar with an abundant production of hydrogen; there is no caramel formed and the acid does not appear to be acetic. Copper, tin, lead, aluminium and cadmium do not appear to be attacked.

C.

THE COLORING MATTER OF YOUNG FUSTIC. J. Schmidt. (*Berlin Ber.*, **19**, p. 1734.)—Fisetin, the yellow coloring matter of young fustic (*Rhus cotinus L.*), has already been investigated by Chevreul and others, and was supposed to be closely related to, or identical with, quercetin.

The author shows that fisetin is not identical with quercetin, but that it occurs as a glucoside (fustin) in combination with tannic acid (fustin tannide).

H. T.

FUSTIN TANNIDE, OR GLUCOSIDE TANNIC ACID OF FISETIN.—Rasped young fustic is extracted with boiling water, the solution purified by the addition of a small quantity of acetic acid and lead acetate. The lead is removed by H_2S, and the tannic acid precipitated by common salt. The filtrate is shaken with acetic ether, which takes up the tannide and leaves it in yellowish, impure crystals on evaporation. H. T.

FISETIN (C_{23}, H_{10}, O_3 $(OH)_6$.—This dye, which results from the decomposition of the above glucoside, is best prepared by extraction with alcohol from the solid extract which comes in commerce under the name of "cotinin." The impurities are removed by acetic acid and lead acetate, and, after the removal of the lead by H_2 S, the dye-stuff is precipitated by the addition of hot water. It is purified by recrystallization from dilute alcohol or acetic acid. The alcoholic solution of fisetin shows the following reactions: Lead acetate, a brilliant orange red precipitate; stannous chloride, an orange yellow precipitate, and acetate of copper, a brown precipitate. Concentrated acids or ammonia give the solution a reddish, yellow color. It reduces Fehling's solution on warming. H. T.

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(*Continued from Vol. CXXII, page 480.*)

GROUP 12*a*.—GAS MANUFACTURE FOR ILLUMINATING AND HEATING, AND APPARATUS THEREFOR, INCLUDING COAL- AND OIL-GAS AND NATURAL-GAS APPLIANCES.

Judges:—Griffith M. Eldridge, Wm. H. Greene, L. B. Hall, Wm. D. Marks, G. M. Ward, Moses G. Wilder, Wm. H. Wahl, *Chm.*

LOWE MANUFACTURING CO., NORRISTOWN, PA.

Water-Gas and Applications thereof.—The exhibit of this company formed a very complete exposition of the capabilities of water-gas for heating, lighting and the generation of power. It embraced a gas-works, complete for the generation of water-gas, having a capacity of 5,000 cubic feet per hour.

The adaptability of the product as a fuel was exhibited in a variety of ways. It was used exclusively in the restaurant for all the uses in cooking, baking, etc., for which solid fuel is commonly used, and by various exhibitors throughout the Exhibition for heating, baking, driving gas engines, and other special uses.

For the utilization of gas for fuel purposes, the company exhibited a variety of ovens, cooking ranges, open-fire stoves, heaters, etc., of special designs.

In a suite of three rooms, occupied by this company, a very attractive display was made of the adaptability of water-gas for domestic lighting and heating. Its display embraced an open fire-place of the usual pattern, various forms of fixtures adapted for a special system of incandescent lighting (which will be treated of later), several forms of combined heating, lighting and ventilating devices, etc., etc.

The general purpose of these exhibitors was to show how, through a single line of pipe laid in the streets of cities and towns, a gas may be distributed, which will serve as an efficient and economical source from which light, heat and power may be obtained. In respect to the variety of applications shown, and the ingenuity displayed in the design of the various devices used, and the mechanical skill and tastefulness exhibited in the construction the exhibit of the company was highly commendable.

Taken collectively, it is safe to say, that, in respect to completeness and variety, it far surpassed any exposition of the capabilities of water-gas ever before attempted.

The time at the disposal of the judges has not been sufficient to enable them to make a careful examination of the question of originality in connection with many features of this interesting exhibit.

Water-gas made by the interaction of steam and carbon at a high temperature, and composed essentially of hydrogen and carbonic oxide, has been known and employed for many years. It is only, however, of late years, that the difficulties in the way of its successful commercial introduction have been practically overcome.

Generally, the improvements that have brought about this result consist of the adoption of methods, whereby the waste of heat in the various steps of the manufacture is reduced to the minimum.

The principal portion of this waste was, formerly, the large consumption of coal required for heating the contents of the generator to the proper temperature to effect the decomposition of the steam, the heat required for the production of the steam, and the heat carried off by the water-gas after its formation.

These elements of waste have been largely reduced by the adoption of devices, whereby the products of incomplete combustion in the generator are regenerated, and caused to impart the heat derived from their subsequent combustion to such heat-storing materials, as fire-brick, etc., suitably placed in a regenerative chamber, or superheater, forming the upper portion of the generator, or connected with it, and through which the steam is caused to pass on its way to the generator.

Further, by using other portions of the waste heat, to heat the air used for blowing up the charge of coal in the generator, and to generate the steam required in the process. By these and other improvements in the construction of the apparatus employed, and in the details of the operation, the quality and quantity of water-gas produced from a ton of coal have been, respectively, considerably increased and improved, and the cost of its production so notably reduced that the problem of introducing it as a fuel for domestic and industrial purposes can no longer be considered as visionary.

It is proper to state in this place, that, with a number of the improvements above noted, and which have substantially con-

tributed to the practical success of water-gas manufacture, the name of THADDEUS S. C. LOWE, of Norristown, is honorably associated, and a number of patents embodying the same have been issued to him, which are accessible for reference.

The devices in the form of ovens, heaters, ranges, stoves, etc., which are embraced in the exhibit of the Lowe Manufacturing Company, are in great variety, and are admirably adapted to serve their intended purposes.

On the general question of the desirability of gaseous fuel, there can be but one opinion. It dispenses with the trouble and annoyance of hauling and carrying coal, and with the removal of dirt and ashes; it is at all times under perfect control; when not wanted it can instantly be extinguished and can instantly be made to give its maximum effect, so that, other things being equal, gaseous fuel possesses incontestable advantages over solid fuel.

Respecting the availability of water-gas for this purpose on the score of economy, the Lowe Manufacturing Company claims to produce from a ton of coal 80,000 cubic feet of water-gas, at a cost of less than ten cents per 1,000. At these figures, twenty-eight pounds of anthracite coal would yield 1,000 cubic feet.

The specific gravity of the Lowe Fuel-Gas, as determined by Dr. Ward, of the judges, is (at 62° F.) ·552 (air = 1).

The 1,000 cubic feet would, therefore, weigh 42·01 pounds. As the theoretical yield of 100 pounds of pure anthracite would be 228·22 pounds of pure gaseous products, the figures claimed to be obtained by the Lowe Manufacturing Company, would be sixty-six and two-thirds per cent. of the theoretical yield of pure carbon. This would leave but thirty-three and one-third per cent. to provide for the consumption of coal for heating the generator, for the production of steam, and the impurities of the coal.

The judges had no opportunity to actually test the question by experiment, but they feel satisfied that the company's estimate of production is too high.

In processes analogous to this in general principles, a practical yield of from 40,000 to 45,000 cubic feet has been obtained, and the judges assume the smaller quantity here named as the safer one to proceed from.

Dr. Greene, of the judges, made an analysis of the gas, taken on October 19th, with the following results:

	By Volume.	*By Weight.*
CO_2,	3·6	9·3
CO,	42·1	69·3
H,	44·5	5·2
N (by diff.),	9·8	16·2
	100·00	100·00

The theoretical calorific equivalent is:

	Composition in Dec. of one Pound.		*Calor. Equiv.*
Nitrogen,	0·162	×	0·0
Carbonic acid,	0·093	×	0·0
Carbonic oxide,	0·693	×	4325·4 = 2997·4
Hydrogen,	0·052	×	62031·6 = 3225·7
Calorific equivalent of Lowe gas in British heat units,			= 6223·1

Taking the yield of gas to be 40,000 cubic feet per ton of coal (2,240 pounds), fifty-six pounds would be sufficient to yield 1,000 cubic feet of gas, weighing, as above noted, 42·01 pounds, and having a theoretical heating effect of (42·01 × 6223·1) = 261,433 units of heat.

As, in the combustion of gaseous fuel, under favorable circumstances, the only loss is from radiation, it is fair to assume that this loss will not exceed ten per cent. This will leave of the above, 235,289 units realizable in practice.

Fifty-six pounds of coal would have a theoretical heating effect of 56 × 14,544 = 814,464 units, of which about fifty per cent. may be assumed to be realizable.

This would leave, under ordinary circumstances, 407,232 units available in practice; from which it appears, under the ordinary conditions of practice, the fuel-gas will produce fifty-three per cent. of the available heating effect of the coal used in making it.

The company states that the cost of production will be less than ten cents per 1,000 cubic feet. We will take ten cents. Taking pea coal at $1.50 per ton, the fifty-six pounds will cost three and three-fourths cents, and, with the assumption of only fifty per cent. of the theoretical effect yielded, the figures would be doubled. When, therefore, solid fuel is utilized, as in ordinary steam generation, the relative cost of coal, and of the fuel-gas which may be obtained from it, under the above assumptions of cost, will be in favor of coal.

This, however, is the conclusion from assumptions, which present the most unfavorable conditions for fuel-gas. For, in practice, the

cheapest grades of coal cannot be used, and the cost of coal generally used for manufacturing and domestic purposes, may be assumed to be $4.50 per ton, which would make the cost of the fifty-six pounds (above employed) equal to eleven and one-quarter cents, which, when compared with the figure of ten cents, which we have purposely taken for the Lowe Fuel-Gas, shows that the fuel-gas can compete economically with solid fuel, where the cost of distribution is neglected.

We should state here in justice to these exhibitors, that they claim to be able to produce fuel-gas considerably cheaper than ten cents per 1,000 feet.

In all the above calculations and comparisons, it should be noted that the judges have presented the case of fuel-gas in the most unfavorable light, so that the conclusions above announced may be considered as an exhibit of the lowest economical results that should be attained in practice. For, it should be stated, that in ordinary practice, especially for domestic service, very much less than fifty per cent of its thermal value, is obtained from the combustion of coal.

As, under these unfavorable assumptions, the results obtained exhibit a comparative economy in favor of fuel-gas, the friends of water-gas have every reason to be satisfied.

Much stress has been laid by certain writers upon the poisonous effects of water-gas, due to the large percentage of carbon monoxide, which it contains, and which is held to constitute a serious objection to its general introduction. This objection, the judges do not deem sufficient to warrant the condemnation of an agent which promises to serve so many useful purposes. The same objection was made to coal-gas, by those who opposed its first introduction, and with as much justification as the opponents of water-gas have at the present.

For the purpose of asphyxiation, either coal-gas or water-gas, will answer quite satisfactorily. It should be remembered, however, that neither of these agents is intended to be breathed, and that the safeguards surrounding the distribution of gases are so perfect that accidents from accidental leakage are of the rarest occurrence.

It is also easy to perfume the gas by slight additions of hydrocarbons, so that $\frac{1}{10,000}$ of one per cent. may be detected by the sense of smell.

While, therefore, it is undoubtedly true that the toxic effects of water-gas are more decided than those of common coal-gas, the judges, in view of the facts above named, do not believe that this constitutes an objection of sufficient weight to warrant the condemnation which some alarmists have cast upon it.

The judges are unanimous in the opinion that the display of the capabilities of water-gas for fuel purposes, made by the Lowe Manufacturing Company, was a most instructive and creditable one.

CARBURETTED WATER-GAS.

The carburetted water-gas was made simply by allowing the gas from the gas holder to pass through the carburetter, and saturate itself mechanically with the gasolene vapor. In this condition it was used principally by the Siemens-Lungren Gas Light Company for lighting a portion of the main avenues. The judges submitted the gas to photometric examinations, with the following results:

PHOTOMETRIC RECORD.

(*Observers: Greene, Marks, Wahl and Ward.*)

Gas consumption per hour,	3·9 cubic feet.
Ignition pressure,	0·15 inches.
Burner U. S. Standard.	
Illuminating value,	18·33 candles.
Equivalent candle-power, at five feet consumption,	23·50 candles.
Candles per cubic foot,	4·7

THE LOWE INCANDESCENT GAS LIGHT.

This light is obtained by allowing the non-luminous water-gas to impinge upon a spiral wire of platinum or platin-iridium. Several forms of this burner are used. Those shown at the Exhibition and examined by the judges were formed of a stout wire of horse-shoe shape, the ends of which were attached to a brass collar, and fitted snugly upon the ordinary lava-tip slit burner. Upon this stout wire there was tied by means of a fine wire of the same material a close spiral of platinum, or platin-iridium, the stout supporting wire being placed on the upper or outer surface of the curve formed by the spiral. The size of the horse-shoe varies with the size of the burner on which it is intended to be used.

They were shown singly, or in groups, or clusters, upon chandeliers of the ordinary pattern, and upon specially designed fixtures, in several of the avenues and in the tastefully decorated rooms occupied by the Lowe Manufacturing Company.

The adjustment of the spiral is such that the flame of the gas shall surround it, so that every part thereof may be equally heated by it. To do this properly requires that the alignment of the spiral with respect to the flame shall be perfect, and that the orifice from which the flame issues shall be kept free from dust or other obstruction, otherwise the unequal brightness of the spiral becomes at once apparent.

Observations of these lights at the Exhibition and at the company's works, at Norristown, warrant the judges in the belief that these requirements present no serious difficulties in practice. When the gas is lighted, the spiral at once becomes brightly luminous, affording a steady uniform light, which at first suggests to the observer the well-known incandescent electric light.

The judges have no data upon which to estimate the average life-duration of these burners, the opportunity for such tests as would be required to determine this question, not having presented itself. It may be proper to state, however, that the Lowe Manufacturing Company claims to have had 2,000 hours of service from experimental burners of this type, without appreciable deterioration.

It is alleged, likewise, that the question of durability is of secondary importance, since when spirals cease to act satisfactorily from any cause, they will still be worth the weight of the metal they contain, and may be exchanged for new spirals at a fractional cost above that of the metal.

The results of photometric tests of a series of these spirals, using Lowe Fuel-Gas, manufactured on the exposition grounds are given herewith:

PHOTOMETRIC RESULTS.

(*1.—Observers: Marks, Wahl and Ward.*)

Gas consumption per hour, ...	9·69 cubic feet.
Ignition pressure, ...	2·25 inches.
Illuminating value, ...	12·85 candles.

Equivalent to 1·33 candles per cubic foot.

(*2.—Observers: Wahl and Ward.*)

Gas consumption per hour, ...	8·31 cubic feet.
Ignition pressure, ...	2·37 inches.
Illuminating value, ...	10·88 candles.

Equivalent to 1·31 candles per cubic foot.

(*3.—Observers: Wahl and Ward.*)

Gas consumption per hour, ...	7·9 cubic feet.
Ignition pressure, ...	2·5 inches.
Illuminating value, ...	12·24 candles.

Equivalent to 1·55 candles per cubic foot.

(*4.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 6·7 cubic feet.
Ignition pressure, ... 1·75 inches.
Illuminating value, ... 8·48 candles.
Equivalent to 1·26 candles per cubic foot.

(*5.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 6·7 cubic feet.
Ignition pressure, ... 1· inch.
Illuminating value, ... 8·41 candles.
Equivalent to 1·25 candles per cubic foot.

(*6.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 5·58 cubic feet.
Ignition pressure, ... 3·25 inches.
Illuminating value, ... 9·94 candles.
Equivalent to 1·78 candles per cubic foot.

(*7.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 5·1 cubic feet.
Ignition pressure, ... 1·5 inches.
Illuminating value, ... 6·85 candles.
Equivalent to 1·34 candles per cubic foot.

(*8.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 3·96 cubic feet.
Ignition pressure, ... 2· inches.
Illuminating value, ... 5·49 candles.
Equivalent to 1·38 candles per cubic foot.

Mean of eight (8) experiments, 1·40 candles er cubic foot.

TABLE SHOWING RECORD OF PHOTOMETRIC TESTS OF THE LOWE INCANDESCENT LIGHTS.—GAS USED, LOWE WATER-GAS.

No. of Experiments.	*Gas Consumed in Cubic Feet per Hour.*	*Pressure at Burner, Inches.*	*Candle-Power.*	*Candles per Cubic Foot.*
1	9·69	2·25	12·85	1·33
2	8·31	2·37	10·88	1·31
3	7·91	2·5	12·24	1·55
4	6·7	1·75	8·48	1·26
5	6·7	1·	8·41	1·25
6	5·58	3·25	9·94	1·78
7	5·1	1·5	6·85	1·34
8	3·96	2·	5·49	1·38
Mean of eight (8) experiments, ...				

From the results of these tests an approximate estimate of the cost of this light, as compared with ordinary illuminating gas, *light for light*, may be made as follows:

If we assume the cost (to consumers) of coal-gas of seventeen candle-power (equal to 3·4 candles per cubic foot) to be $1.50 per 1,000, the cost of water-gas must not exceed sixty-one and three-fourths cents per 1,000. If we assume coal-gas of seventeen candle-power to cost the consumer $1 per 1,000, the cost of water-gas must not exceed forty-one and one-sixth cents per 1,000; or, in round numbers, sixty and forty cents, respectively.

In other words, to compete on equal terms with ordinary illuminating gas, the Lowe incandescent light will have to be supplied at two-fifths the cost of the former.

Whether such economy can be obtained, depends to a large extent upon the cost of distributing the gas, which will depend largely, in turn, upon the amount of consumption for fuel and lighting purposes; so that any estimate based upon the cost of gas in the holder, will be very misleading. On the question of economy, therefore, the judges refrain from expressing an opinion.

The judges availed themselves of the opportunity afforded them after the close of the Exhibition, to make a second series of photometric measurements of the Lowe incandescent burners, with the object of verifying and controlling the results of their first set of observations. The results are given below, and show a satisfactory uniformity between the two sets of observations.

PHOTOMETRIC RECORD.—(Second Series.)

(*1.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ... 7·8 cubic feet.
Ignition pressure, ... 2·3 inches.
Illuminating value, ... 10·6 candles.
Equivalent to 1·36 candles per cubic foot.

(*2.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ... 9·9 cubic feet.
Ignition pressure, ... 2·1 inches.
Illuminating value, ... 12·83 candles.
Equivalent to 1·29 candles per cubic foot.

(*3.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ... 4·74 cubic feet.
Ignition pressure, ... 2·75 inches.
Illuminating value, ... 6·85 candles.
Equivalent to 1·45 candles per cubic foot.

Mean of three experiments, 1·37 candles per cubic foot.

TABLE SHOWING RECORD OF PHOTOMETRIC TESTS OF LOWE INCANDESCENT BURNERS.—GAS USED, LOWE WATER-GAS.

No. of Experiments. (2d Series.)	*Gas Consumed in Cubic Feet, per Hour.*	*Pressure at Burners, Inches.*	*Candle-Power.*	*Candles per Cubic Foot.*
1	7·8	2·3	10·6	1·36
2	9·9	2·1	12·83	1·29
3	4·74	2·75	6·85	1·45
Mean of three experiments,				1·37

The judges make the following recommendation: To the Lowe Manufacturing Company, Norristown, Pa., for substantial improvements in the manufacture of water-gas, and in appliances for using water-gas for fuel; for ingenuity displayed in methods for using water-gas for illuminating purposes, and for general excellence of collective exhibit of the capabilities of water-gas—

A SILVER MEDAL with a reference to the Committee on Science and the Arts, for such higher award as it may deem proper to make.

DESTRUCTION OF TROUT BY MOSQUITOES.—A recent *Bulletin* of the United States Fish Commission contains the following interesting account: "In the middle or latter part of June, 1882, I was prospecting on the headwaters of the Tumichie Creek, in the Gunnison Valley, Colorado. About 9 o'clock in the morning, I sat down in the shade of some willows that skirted a clear but shallow place in the creek. In a quiet part of the water, where their movements were readily discernable, were some fresh-hatched brook or mountain trout, and circling about over the water was a small swarm of mosquitoes. The trout were very young, still having the pellucid sack puffing out from the region of the gills, with the rest of the body almost transparent when they swam into water lighted up by direct sunshine. Every few minutes these baby trout, perhaps to get the benefit of more air, would come up, so that the top of the head was level with the surface of the water. A mosquito would then light down and immediately transfix the trout by inserting its proboscis, or bill, into the brain of the fish, which seemed incapable of escaping. The mosquito would hold its victim steady until it had extracted all the life juices, and when this was accomplished, and it would fly away, the dead trout would turn over on its back and float down the stream. I was so interested in this before unheard-of destruction of fish that I watched the mosquitoes for more than half an hour, and in that time over twenty trout were sucked dry and their lifeless bodies sent floating away with the current. I have been unable by inquiry to ascertain if others have observed a similar destruction of fish. I am sure the fish were trout, as the locality was quite near the snow line, and the water was very cold, and no other fish were in the stream at that altitude. From this observation I am satisfied that great numbers of trout, and perhaps infant fish of other varieties in clear waters, must come to their death in this way; and if the fact has not been heretofore recorded it is important to those interested in fish-culture." C.

SUPPLEMENT TO CATALOGUE OF DUPLICATES IN THE LIBRARY FOR SALE OR EXCHANGE.

American Association for the Advancement of Science. Proceedings for 1884 and 1886. In three vols., ... 1880

American Association for the Advancement of Science. Programme of Thirty-fifth Meeting. Buffalo, 1886. p. 157, ... 1892

American Chemical Society. Journal. Nos. 7–10, vol. 6, and Nos. 1, 2, and 6–10, vol. 7. New York, 1884–85, ...

American Journal of Photography. Philadelphia. June and July, 1886, ...

American Philosophical Society. Philadelphia. Proceedings. Nos. 15, vol. 2; 46, vol 5; 53, 54, vol 6; 61, 63 (two copies), 64, vol. 7; 65, 66, vol. 8; 67, (two copies), 69, 70, 72, vol. 9; 73–80, vol. 10; 81–84, vol. 11; 94, vol. 14; 97, vol. 16; 102, vol. 18; 111, vol. 20, ... 1740

American Society of Mechanical Engineers. Transactions. Vol. 7. New York, 1886, ... 1921

Apprentices' Library Company. Sixty fourth Annual Report of the Managers. Philadelphia, 1884. p. 1901

Australia. Official Catalogue of Natural Products of N S. Wales at Philadelphia, 1876. Sydney, 1876. p. 104, ... 1842

Bannister, L. Something About Natural Gas. New York, 1886. p. 40. Two copies, ... 1906

Bilgram Bevel Gear Cutter. Report of the Committee on Science and the Arts. FRANKLIN INSTITUTE. Philadelphia, 1886. Twenty-nine copies, ... 1825

Blodget, L., y E. T. Freedley Filadelfia y sus Industrias. Filadelfia, 1885. p. 74, ... 1883

Blodget, L., and E. T. Freedley. Philadelphia and its Industries. Philadelphia, 1885. p. 87, ... 1882

Bolton, H. C. Recent Progress in Chemistry. p. 25, ... 1869

Brush Electric Company. Catalogue of Machinery, Batteries, Carbons, etc. p. 36, ... 1832

Bureau of Navigation. Hydrographic Office U. S., Pilot Chart. October and November, 1886 . . . . 1225, 1923

Bureau of Navigation, U. S., Naval Professional Papers, No. 18. Training of Enlisted Men. Washington, 1885. Bound, ... 1822

Bureau of Navigation. U. S., Naval Professional Papers. No. 20. Naval Brigade and Operations Ashore. Washington, 1886. Bound, ... 1840

Bureau of Statistics. Treasury Department, U. S., Quarterly Report of the Chief. No. 4, 1885–86. Washington, 1886. Two copies, ... 659

Carr, Wm. Wilkins. Legal Protection of the Present Water-Supply for Philadelphia, 1886. p. 46, ... 1907

Castner, H. Y. New Process for the Production of the Metals of the Alkalis. Philadelphia, 1886. Thirty-four copies, ... 1884

Castner, H. Y. New Process for the Production of the Alkali Metals. Philadelphia, 1886. Eleven copies, ... 1872

Central Committee of U. S. Proceedings on the Industrial Exhibition of 1851. Washington, 1850. p. 40, ... 1858

Civil Service Commission, U. S. Second Annual Report, 1884–85. Washington, 1885. p. 1900

Chase, P. E. Herschel *vs.* Jevons, *et al.* FRANKLIN INSTITUTE, Philadelphia, 1886. Thirty-four copies, ... 1828
Chemical News. Vol. 47, incomplete; vol. 48 and vol. 49, complete, and No. 1316, vol. 51. London, 1883–86, ...
Commissioner of Railroads. Annual Report to Secretary of Interior for 1883. Washington. Bound, ... 1924
Continental Underground Cable Company, The. Camden, ... 1887
Continent, The. February 21 and 28, 1883 Philadelphia, ...
Courtonne, E. Langue Internationale Nèo-Latine. Nice, 1884, ... 1876
Cowles, E. H. and A. H. Report of the Committee on Science and the Arts on the Process and Furnace for the Reduction of Refractory Ores, etc. FRANKLIN INSTITUTE. Philadelphia, 1886. Three copies, ... 1827
Cutcheon, B. M. Speech on Fitz-John Porter. Washington, 1886. p. 59, . . 1895
Elderhorst, Wm. Manual of Blow-Pipe Analysis and Determinative Mineralogy. Third edition. Philadelphia. N. D., ... 1875
Electrical Conference at Philadelphia, Report. 1884. Washington, 1886. p. 86. Forty-six copies, ... 1889
Forney, M. N. Evolution of the American Locomotive. Philadelphia, 1886. p. 23. Forty-one copies, ... 1866
Frankland, Edward. How to Teach Chemistry. Edited by Geo. Chaloner. Philadelphia, 1875. 12 mo., p 83. Bound. 1918
Haupt, L. M. Harbor Studies, etc. Philadelphia, 1886, ... 1870
Hepburn, W. P. Speech on the Secretary of War. Washington, 1886, ... 1894
Houston, E. J. Glimpses of the International Electrical Exhibition. Philadelphia, 1886. Bound, ... 1846
Indian Meteorological Memoirs. Vol. 1. Calcutta, 1876–81. Bound, ... 1823
Internal Revenue. Report of the Commissioner for Year ending 1882. Washington. p. 136, ... 1909
Ives's Process of Isochromatic Photography. Report of Committee on Science and the Arts. Philadelphia, 1886. Thirty-four copies, ... 1868
Jackson, F. E. Effect of Inertia of Reciprocating Parts in Modifying Force Transmitted to the Crank-Pin. Philadelphia, 1886. Five copies, . . . 1835
Karsten, C. J. B. Manuel de la Mètallurgie du Fer Traduit de l'Allemand, par F. J. Culman. Second edition. 3 vols. Metz, 1830, ... 1784
Kelley, W. D. Speech on E. M. Stanton. Washington, 1886. p. 12, ... 1893
Kelley, W. D. Speech on Fitz-John Porter. Washington, 1886. p. 28, . . . 1896
Lehmann, C. G. Atlas der Physiologischen Chemie. Leipzig, 1853. Bound. Incomplete, ... 1830
Lowe, T. S. C. Water Gas and its Uses. A Paper read before the Committee on Science and the Arts. Also, Report of the "Novelties" Exhibition. Philadelphia, 1886. Four copies, ... 1865
Marks, W. D. Inquiry touching the Law of Condensation of Steam. Philadelphia, ... 1888
McElderry, H. Description of Models of Hospitals and Tents. Exhibited at New Orleans by Medical Department, U. S. A. New Orleans, 1884–85. p. 23, ... 1841
Philadelphia Exhibition, 1876. United States International Exhibition. Organization Work Proposed, etc. Philadelphia, 1876. p 104, ... 1843
Mexico. Monthly Reports upon the Commerce and Agriculture. February, April, and May, 1886, ... 1864

Michigan State Horticultural Society. Twelfth Annual Report. 1882. Lansing, 1883. Bound, ... 1910
Mint, U. S. Report of the Director for 1885. Washington, 1885, ... 1899
Mordecai, A. Report of Experiments on Gunpowder made at Washington Arsenal in 1843-44. Washington, 1845, ... 1908
New Jersey Archives. Vol. 10. Newark, 1886. Bound, ... 1890
Newport Historical Society. First Annual Report. 1886. p. 44, ... 1897
Paris Exhibition, 1878. Catalogue de la Section Japonaise. p. 47. Two copies, ... 1854
Paris Exhibition, 1878. Catalogue des objects Exposés par Schneider et Cie. Paris, 1878. p. 77, ... 1850
Paris Exhibition, 1878. Catalogue of A. Ransome & Co. Wood-Working Machinery. p. 54, ... 1853
Paris Exhibition, 1878. Collection du Ministère des Finances Neerlandais. Amsterdam, 1878. p. 26, ... 1855
Paris Exhibition, 1878. Grèce at l'Exposition. Athènes, 1878, ... 1851
Paris Exhibition, 1878. Hand-Book to British Section. G. C. M. Birdwood. London. p. 126, ... 1856
Paris Exhibition, 1878. Ministry of Agriculture and Commerce. Regulations Fixing the Nature of the Awards. Paris, 1878. p. 11. Two copies, . . 1852
Paris Exhibition, 1878. Section Belge. Catalogue Officiel des Œuvres d'Art, etc. Bruxelles, N. D. p. 346. Maps, ... 1860
Patent Office, British. Alphabetical Indexes. January-February, April-July, October-November, 1885, and January-April, 1886. In parts, ...
Patent Office, British. Subject Matter indexes. January-February, April-November, 1885. January-April and June, 1886. In parts, ...
Peabody Museum of American Archæology and Ethnology. Eighteenth and Nineteenth Annual Reports, in one volume. Cambridge, 1886, ... 1839
Pennsylvania Academy of the Fine Arts. Catalogue of American Exhibition of British Art. Philadelphia, 1858. 8°., p. 27, ... 1863
Pennsylvania State College. Agricultural Bulletins. No. 11, ... 1920
Pennsylvania State College. Catalogue, 1885-86. Circular, 1884-85. State College, Pa., 1885-86, ... 1911, 1912
Phelps Induction Telegraph. Report of the Committee on Science and the Arts. FRANKLIN INSTITUTE. Philadelphia, 1886. Two copies, ... 1824
Philadelphia City Directory. Gopsill's, 1877, ... 1903
Philadelphia City Directory. McElroy's. 1860 and 1866, ... 1874
Philadelphia Exhibition, 1876. Catalogue of Products Exhibited by Motala Iron and Steel Works, Sweden. Philadelphia, 1876. p. 16. Two copies, 1861
Philadelphia Exhibition, 1876. Catalogue of the Educational Exhibit of Pennsylvania, with Appendix. Lancaster, 1876, ... 1847
Philadelphia Exhibition, 1876. Exhibit of Kentucky's Educational System. Henderson. Frankfort, 1876. p. 37, ... 1848
Philadelphia Exhibition, 1876. Official Bulletin. No. 1, two copies; and No. 3. Philadelphia, 1877, ... 1844
Philadelphia Exhibition, 1876. Russian Section. St. Petersburg, 1876. p. 28, . . 1862
Philadelphia Gas Works. Why they should remain under Municipal Control. p. 15, ... 1898
Philadelphia Photographer. January 16 and February 6, 1886, ...

Philadelphia. Proceedings at the Laying of the Corner-stone of the New Public Buildings on Penn Square. July 4, 1874. p. 63 and plates, ... 1891

Pryibil, P. Catalogues of Machinery for Working Brass, Wood, Ivory, etc. New York, 1885. Three copies, ... 1838

Publishers' Trade List Annual, for 1874. New York. Bound, ... 1926

Pusey, Joshua. Suggestions Toward a Simplified System of Weather Signals. FRANKLIN INSTITUTE. Philadelphia, 1886. Four copies, ... 1826

Ramsey's Car-Transfer Apparatus. Report of Committee on Science and the Arts. Philadelphia, 1886. Ten copies, ... 1833

Randolph, N. A. Inorganic Foods. Philadelphia, 1886. Five copies, ... 1834

Revue International de l'Enseignement publiée par la Société de l'Enseignement Supérieur. Paris, 1886. ue, ... 1845

Richmond, George. The Refrigeration Machine as a Heater. FRANKLIN INSTITUTE. Philadelphia, 1886. Thirty-one copies, ... 1829

Rogers, H. R. New Philosophy of the Sun. Dunkirk, N. Y., 1886. p. 27. 1837

Rossiter, N. L. Silk and the Silk Worm. Third edition. Philadelphia, 1881. Seven copies, ... 1881

Santiago. The Second International Exhibition of Chili, South America. New York, 1874. p. 29, ... 1859

Schlesinger, W. M. System of Electric Transmission, 1886. p. 10. Seven copies, ... 1878

Scranton Board of Trade. Report on Powdered Anthracite and Gas Fuel. 1886, 1914

Smith, O. Flow of Metals in the Drawing Process. Philadelphia, 1886. Five copies, ... 1885

Smithsonian Institution. Annual Report for 1884. Part 2. Washington, 1885, ... 1904

Snyder, M. B. Electrical Exhibition and Pure Research Philadelphia, 1886. p. 19 Twenty-six copies, ... 1915

Société des Sciences Industrielles de Lyon. Annales. No. 3, 1884. and No 3, 1885, ... 1877

State Department, U. S. Consular Reports Nos. 28, 30 and 66. Washington, 1883, ... 1905, 1913

Tatham, W. P. The Dynamometer. Philadelphia, 1886. Thirty-two copies, . 1886

Thurston, R. H. Friction of Non-Condensing Engines. Philadelphia, 1886. p. 19. Five copies, ... 1916

Thurston, R. H. The Great Brush Dynamo. Philadelphia, 1886. p. 9. Thirty-nine copies, ... 1867

Trautwine, J. C. Field Practice of Laying out Circular Curves for Railroads. Twelfth Edition. New York, 1886. Bound, ... 1836

Turnbull, L. Memoir of James Aitken Meigs. Philadelphia, 1881, ... 1902

Turner, E. Elements of Chemistry. Fifth American from Fifth London edition with Notes By F. Bache. Philadelphia, 1835, ... 1873

United States Commission of Fish and Fisheries. Part II. Report of Commissioner for 1883. Washington, 1885. Bound, ... 1831

United States National Museum. Bulletin, Nos. 1-4 and 6-10. Washington, 1875-77, ... 1925

Vienna, Austria. Report upon the International Electrical Exhibition. 1883. Parts 8 and 9. In German. Incomplete, ... 1849

Vienna Universal Exhibition, 1873. General Regulations for Foreign Exhibitors and Commissioners. Washington, 1872. p. 28, ... 1857

War Department, U. S. Report of the Board of Fortifications or other Defenses, Appointed by the President of the United States, under Act approved March 3, 1885. Washington. 1886. p. 393. 59 plates. 1919

Washburn Observatory, Publications. Vols. 3 and 4 Madison, 1885, ... 1922

Woodbridge, J. L. Turbines. Philadelphia, 1886. p. 25. Five copies, . . . 1917

Yale College Observatory. Report for the year 1885-86. p. 15, ... 1879

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PURIFICATION OF THE WATER-SUPPLIES OF CITIES.

BY ALBERT R. LEEDS, PH. D.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Thursday, December 23, 1886.*]

THE LECTURER was introduced by Dr. Wahl, the Secretary of the INSTITUTE, and spoke as follows:

ACTING UNDER INSTRUCTIONS from the Aqueduct Boards of Newark and Jersey City, I spent the past summer in examining the water-supplies of the large cities in England and Scotland. Many of these cities have already passed through crises in the history of their water-supplies, similar to those at present agitating American communities. It is of the remedies which they have adopted, and of the pressing needs of Philadelphia, Albany, Newark, Jersey City, Wilmington, Washington and other places, that I propose to speak this evening.

Our modern manufacturing towns increase in population with such rapidity that they soon find their local sources of water-supply insufficient in quantity, and dangerous to health from pollution by

sewage and factory waste. Then follows a more or less prolonged period of bitter controversy. It matters not how plain the fact of gross pollution may be; the fact is denied. In case the chemical testimony agrees with that of the senses, and water which is dirty, foul-smelling and bad-tasting, is found by the chemist to be impure, his honesty and ability are assailed. Either his results are declared false, or it is asserted that they mean just the reverse of what he himself says. Other experts are employed, and the local water-supply, though it may contain the sewage of 10,000 or 100,000 people, is joyfully discovered to be extremely pure, and second in purity to none in the country. But at last, after years of denial, during which the public health has severely suffered, the fact of pollution is admitted, and the community resorts to one or more of the three following remedies:

(1.) It abandons local for remote sources, such as springs, lakes, rivers, or areas of upland drainage.

(2.) It sinks artesian wells, or deep wells, or subterranean galleries.

(3.) It purifies the polluted local supply.

In the study of this subject, there is no source of information more valuable than the blue books containing the minutes of inquiry before the Royal Commissions of 1851 and 1868 upon the supply of London. It is there stated that at first London drew its supply directly from the Thames, where it flowed through the town, at London Bridge. This was in 1581, and a century later (1691) the Thames was again drawn upon at Charing Cross, and this intake remained in use as late as 1829. Again, in 1723, the Chelsea Water Works were established, and in 1785 those at Lambeth. Whilst some part of the water-supply was derived from springs in the chalk formation at Chadwell (brought in through a canal called the New River, in 1613), and another part from the river Lee (introduced by the East London Water Works Company, in 1806), yet as late as the year 1829, the metropolis was principally supplied by water taken from the Thames within the reach of the tidal flow. But in 1829, a Royal Commission, consisting of Telford, Brande and Roget, was appointed to inquire into "the description, the quality and the salubrity" of the water. They reported "that the Thames water, when free from extraneous substances, was in a state of considerable purity; but as it

approached the metropolis it became loaded with a quantity of filth which rendered it disgusting. It appeared, however, that a very considerable part, if not the whole, of this extraneous matter, might be removed by filtration through sand, and the Commission decided that it was perfectly possible to filter the whole supply with the requisite rapidity and within reasonable limits of expense." Stimulated by this report, and alarmed, probably, at the prospect of a sweeping change of the sources of supply, the companies directed their attention to the purification of the water by filtration. It was soon found that the only appropriate material for mechanical filtration on a large scale, was fine sand; but the great practical difficulty was to prevent the sand from becoming clogged, and to find an easy, practical and cheap method for its renewal. After long experimentation, a means was discovered of getting over these difficulties. It was found that by far the greater quantity of the impurities was held in suspension by the agitation and motion of the water, and that if it was allowed to stand for some time at perfect rest, in a reservoir, the heavier and grosser particles were deposited by simple subsidence, leaving only a small proportion of lighter and finer matters to be dealt with by filtration. It was also found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass, but was stopped at its upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and, when it had become too much diminished, to put on fresh sand.

In accordance with these suggestions, the first large filter, which had an area of one acre, was put into use by the Chelsea Company, in 1829.* It worked well, so well indeed, that it led to the well-nigh universal practice of filtration in England. Our failure to do the same in this country, shows that in this respect we are behind the age.

But about the time of this first use of filters in England, the disturbing ideas of modern sanitary science took their rise; that unspeakable abomination, the domestic cesspool attached to a city house, began to be abolished; drainage and sewerage works were

* Royal Comm. Water-Supply, 1868.

established, and the amount of impurities carried to and fro under London Bridge was increased enormously.

This agitation kept on growing, until, in the year 1834, the engineer, Mr. Telford, recommended that the Thames should be abandoned. This was not done, but in 1851, a Royal Commission, consisting of Profs. Graham, Miller and Hofmann, recommended that while the supply should still be drawn from the Thames, the points of intake should be removed above the influence of tidal flow (*i. e.*, above Teddington Lock). They made other recommendations, which were incorporated into an Act, passed in 1852, regulating the water-supply of the metropolis. In this act, the two clauses of greatest significance to us, are, (1): That every storage reservoir within five miles of St. Paul's should be covered; and (2), That all water supplied for domestic use *should be effectually filtered, unless it is pumped from wells direct into covered reservoirs.*

A mere statement of the law, which was passed after a quarter of a century of discussion by the most eminent engineers, chemists and law-makers of England, is a more emphatic testimony to the fundamental importance of the provisions therein contained, than any argument I am able to make.

This law led to certain results throughout England, which I trust will become universal. These are:

(1.) The education of public opinion to such a point as to demand sources of city water-supply, actually and visibly free from pollution. The wealthiest communities like Glasgow, Manchester and Liverpool, have deemed it a wise investment of great sums of money to obtain sources absolutely free from suspicion and reproach.

(2.) The construction of large, and in some cases vast, reservoirs with the object, not merely of safety, but also of allowing opportunity for the dissolved organic matters to oxidize, or to be carried by subsidence along with the suspended mineral matters to the bottom.

(3.) Effectual filtration. And it should be noted, that when the Act of 1851 required the London companies to filter the water, under very heavy penalties, the water referred to was that taken from the Thames above Teddington Lock, which water the Commission had previously found to be "perfectly wholesome,

palatable and agreeable." Still more striking instances of the estimate put upon filtration, as a process indispensable to the excellence of city water-supply, were frequently brought under my personal observation, and some I shall mention later.

(4.) The preservation of the water, after it has been filtered, in covered storage reservoirs.

The good effects of the Act of 1851 speedily became apparent. The water companies expended £2,500,000, with the result, according to the examinations of Prof. Hofmann and Mr. Blyth, made in 1856, of bringing about "a very positive and considerable diminution in the amount of organic matter. This, though doubtless due chiefly to the removal of the intake to a point above the tideway of the Thames, was also attributed in great degree to the considerable improvement which had taken place in the collection, filtration, and general management of the supply of water."

But, fortunately, the public was not satisfied. In pursuance of the recommendations of the Royal Commission of 1865, on the pollution of rivers, the admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary stream or water-course within three miles of its junction with the Thames, was declared illegal, with heavy penalties. In 1866, 5,596 lives were destroyed in London by cholera, and although this visitation was subsequently attributed to the polluted water of the Ravensbourne and the foul unfiltered water from the reservoirs at Old Ford on the river Lee, yet it so alarmed the community that the Commission of 1866 was appointed to make a far more extended inquiry than ever before, and to ascertain what supply of unpolluted and wholesome water could be obtained, by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs, at a sufficient elevation for the supply of London and the principal towns of England. Now it is a well-known fact that the recommendations of the very distinguished engineers came to naught, so far as London was concerned, though they are at present bearing fruit in connection with Manchester and Liverpool.

It is well worth our while to inquire why such was the case. Mr. Bateman's plan was to bring the waters collected from the drainage areas at the head of the river Severn in Wales (including the drainage area of the Vyrnwy) by gravitation through an

aqueduct 180 miles in length, and capable of conveying 230,000,000 gallons per diem. Messrs. Hemans and Hassard proposed to bring the waters of Lakes Thirlmere, Ullswater and Haweswater, through conduits, tunnels and pipes equivalent in their carrying-capacity to a river 30 feet wide and 10 feet deep, over a length of 270 miles. These plans, which were considered the best, were reported upon unfavorably, principally on account of the cost, the estimated expense of Mr. Bateman's scheme being £55,000,000, and that of the Cumberland lake scheme still greater.

This report decided the future supply of the metropolis, and confined it to local sources The supply from Lake Thirlmere has already been appropriated by the city of Manchester. The water will be brought in a tunnel nine feet square to the reservoirs at Prestwich, on one side of Manchester, a distance of ninety-five miles, and continued thence to reservoirs on the other side of Manchester, a distance of 110 miles. Mr. Hill, the engineer of the new supply, informed me that the first 10,000,000 gallons are estimated to cost £2,000,000, inasmuch as the tunnels of full size are to be constructed at once, and connected by a forty-inch iron pipe where siphons are necessary. The second 10,000,000 gallons are estimated to cost only £400,000. The land damages to persons living around the lake and along the tunnel are £225,000.

The supply from Vyrnwy Lake has been appropriated by Liverpool. This artificial lake is to be created by a dam, which, at its top, will have a length of 1,173 feet, and will rise to a height of 144 feet above the bed-rock and 84 feet above the bed of the existing river. Its length will be 4¾ miles, its area 1,165 acres, and its greatest depth of water about 84 feet. The aqueduct from the lake to the existing Prescot Reservoir, nine miles east of the Liverpool Town Hall, is sixty-eight miles. It will consist mainly of tunnels, through which the ultimate supply of 40,000,000 gallons a day may be passed without filling them, and of three lines of pipes, each having an internal diameter varying according to the fall of the sections from thirty-nine to forty-two inches. All this water from the Welsh mountains will be subjected to filtration through sand-filters, the Oswestry reservoir and the three reservoirs for filtered water having an aggregate storage capacity of 54,549,500 gallons.

In one very important particular, the Commission of 1866 was

certainly in error. It thought a probable increase of population to 4,500.000 or 5,000,000 would have to be provided for, and a maximum daily supply of 200,000,000 gallons, though the time for such an extended provision would be very remote. As a matter of fact, the population supplied by the companies in May of this year, was 5,274,542, and the average daily supply during the month was 160,388,316 gallons. Of this, more than half, or 82,366,466 gallons, came from the Thames, and the balance from the river Lee, and from certain chalk springs in the valleys of the Lee and Thames, and from twenty-one deep wells sunk into the chalk formation to the north and south of London. There are fifty-four *subsiding reservoirs for unfiltered water*, with an area of 465 acres, and an available capacity of 1,290,100,000 gallons, and fifty-three *covered reservoirs for storage of the water after filtration*, with a capacity of 160,002,000 gallons. The number of filter-beds is ninety-nine, with an area of ninety-eight acres. Of this surface, ninety-two acres were cleansed during the month of May, some of the filter-beds being cleansed once and partly gone over again during the month. The maximum permissible rate of filtration is two feet per hour and per square foot of surface, but as a matter of fact, the actual rate in the month of May last was generally much smaller than this, some filters passing only one and one-third feet. The construction of the filters varies greatly, the top layer, however, being in all cases fine sand, in depth from two to four and one-half feet.

From the published analyses it appears that the quality of the water supplied to London is usually satisfactory, though at times results are obtained adverse to that portion of it which is derived from the Thames. The population of the drainage area of the Thames is very large, and although the towns located therein are compelled to purify their sewage, yet much polluting material from them and from the floating population on the river, finds its way into the river.

Leaving for the present the history of the largest experiments hitherto made in the way of purification of a polluted water-supply, I shall ask your attention more particularly to the methods by which such purification may be effected.

Artificial Aëration.—One of the easiest and most inexpensive

methods of improving the quality of water, is by means of artificial aëration. The importance of natural aëration has been recognized from time immemorial, and the effect of tumbling down natural falls and rapids, passing over artificial dams, and of agitation by winds and storms, in keeping water lively and sweet, is too well known to need more than passing mention. It is of especial interest to us that this mode of improving water was first applied to city water-supply in consequence of the extremely offensive taste and odor of the Schuylkill water in January and February, 1883. The fact that the analyses revealed the presence of a large amount of sewage in the Fairmount water, did not explain its peculiar offensiveness at that season, for there have been times, before and since, when it contained even more sewage and was not so unpalatable. But it appeared to me very noteworthy that the oxygen which ought to be present in a state of solution, was largely deficient. Much of it had been used up in the oxidation of the sewage, and the river, being ice-bound from its source to Fairmount Dam, had no opportunity of taking from the atmosphere sufficient oxygen to replace that which had been lost.

Reflecting upon these facts, I thought it worth while to try the effect of submitting the disgusting samples from Fairmount Pool to artificial aëration. I found that they not only took up from the air forced through them, the oxygen they lacked, but also that much of the sewage to which their offensiveness was due, was destroyed. These experiments suggested to me the idea of pumping air into the lower ends of the mains at the pumping-stations. This way of introducing the air was not only the easiest and simplest, but it also afforded an opportunity of placing the mixture of air and water under a maximum pressure. Air, as is well known, consists of twenty-one parts by volume of oxygen and seventy-nine parts of nitrogen; but the oxygen is more soluble in water than the nitrogen, and therefore the greater the pressure to which a mixture of air and water is subjected, the larger is the relative amount of oxygen made to enter into solution.

The study of the subject received fresh impetus from the condition of the water-supply of Hoboken in the latter part of July, 1884. At that time, the oxygen in a number of samples from the Hackensack River, whence the supply of Hoboken is derived, fell to 3·87 c. c. per litre, and the total dissolved gases to 14·93 c. c.

Contemporaneously, the same waters, when impounded in the reservoir, became covered with a scum several inches in thickness, consisting largely of *Oscillariæ*. These quickly died, and yielded up a dark blue coloring matter (*the Phocoryan of Cohn*). Finally, this great accumulation of vegetable growth passed into a state of active decomposition, attended with the formation of white foam, and the liberation of large volumes of carbonic acid and other gases. The water for ten days previous had been too nauseous to drink, but the whole succession of phenomena above described took place within twenty-four hours, the vast development of algæ, their breaking up with evolution of green and blue coloring matter, and their final decomposition occurring with astonishing rapidity. The entire reservoir had the appearance of an enormous dyeing vat, covered with dark green and blue dye-stuffs.

A repetition of the same disastrous sequence of events was threatened on September 14th, when the percentage of dissolved oxygen fell to four cubic centimetres, and at the same time a growth of algæ began in the reservoir. But meanwhile arrangements had been perfected in anticipation of this catastrophe, and by pumping air under pressure into the mains, the percentage of total dissolved gases was raised from 15·9 cubic centimetres to 21·2 cubic centimetres. The green scum on the reservoir disappeared, and the taste and smell of the drinking-water became satisfactory.

In November, 1884, a preliminary experiment was instituted at the Fairmount Pumping Station, an air-pump being attached to the main at that point. The aërated water was pumped into the Corinthian Basin through the forty-eight-inch main, a distance of 3,000 feet. The results of this experiment were so encouraging, that the Chief-Engineer, Col. Ludlow, obtained air-compressors for all the pumping-stations At only one of them, however, has the process been applied, namely, at Belmont, the other mains being too leaky to permit of its being used.

At this station, the water has been charged with twenty per cent. of its volume of air, and the change in composition thereby effected is strikingly illustrated in the following results, which give the composition of the water before it enters the pumping-main, and as it is discharged therefrom.

	PARTS PER 100,000.	
	Non-aerated.	*Aerated.*
Free ammonia,	0·017	0·004
Albuminoid ammonia,	0·011	0·007
Oxygen required to oxidize organic substances,	0·133	0·117
Nitrous acid,	0·0008	none
Nitric acid,	0·45	0·54
Total solids,	9·00	8·70

It will be seen that the albuminoid ammonia has diminished nearly forty per cent.; and, what is the most noteworthy feature of all, the nitrous acid has undergone complete oxidation, none being present in the aërated sample. At the same time, by oxidation of the nitrogenous portions of the organic matter, the nitric acid has been increased twenty per cent.; and by oxidation of the organic constituents in general, the total solids have been diminished from nine parts per 100,000, to 8·7 parts.

The process has now been applied to the entire water-supply of Hoboken, amounting to 4,000,000 gallons per diem, for more than two years, and during this time the unpleasant taste which caused its first application, has never reappeared.

Similar experience in Brooklyn has caused the process to be used in connection with the water obtained from driven wells. This driven well water has been used in the Greenwood Cemetery to feed a number of artificial lakes arranged to beautify the grounds. Last summer, I was asked to examine the water in the reservoir into which the driven well water is first pumped, and to devise a means if possible for preventing the enormous growth of plants therein. The growth, on examination, proved to be diatomaceæ, particularly of the species *Navicula viridis*, and the green vegetable substance which by its decay rendered the water offensive, was the slime secreted by these diatoms. Two facts were prominent. The one was that the diatoms could be made to grow very rapidly when exposed in open jars to sunlight; the other, that the water of the reservoir was very deficient in dissolved oxygen. It contained only 2·32 cubic centimetres of oxygen in the litre, and the enormous amount of 4·97 cubic centimetres of carbonic acid. I advised the covering of the reservoirs to exclude sunlight. The authorities were opposed to so doing, because it destroyed the very result aimed at in providing the reservoir and ponds, which was to beautify the park. Then I advised the use

of an air-compressor. This was installed, and the result is given in the following letter from the consulting engineer:

NOVEMBER 27, 1886.

DR. ALBERT R. LEEDS:

Dear Sir:—In answer to your inquiry concerning the trouble at the Greenwood Cemetery reservoir, I would state that the water, fresh from driven wells, when delivered into the reservoir, began to develop decaying vegetation, which in a short time rendered the water offensive to taste and smell; that immediately on receipt of your report and recommendation, last June, I set up an ordinary compressor, and pumped air into the mains under a pressure of about eighty pounds to the square inch, allowing it to escape through the reservoir with this result. At first there was no perceptible effect, but upon increasing the amount of air supplied to the water, to the extent of about ten per cent. of the free air to an equal volume of water, the trouble in the reservoir disappeared. Since that time air has been freely supplied whenever there appeared to be any recurrence of the growth of vegetation in the reservoir, and there has been no return of the offensive taste and smell. Respectfully submitted,

CHAS. B. BRUSH,
Con. Eng. Greenwood Cemetery.

Covered Reservoirs.—In May of this year, the water from the driven wells supplying the city of Jamestown, in Western New York, was similarly affected, the reservoir containing several species of diatomaceæ, among which the *Cocconema Lanceolata* was the most abundant. Certain of the protoccaceæ, especially various species of Scenedesmus and certain genera of Zygnemaceæ, including different species of Spirogyra, were also present. The water in the driven wells (May 22d) had a temperature of only 48°, but that in the reservoir was over 80°, and the development of the spores in the deep-well water was correspondingly rapid. The suggestion to cover the reservoir was carried out in this case, and the aquatic plants disappeared. Similar troubles, and the development of a variety of odors chronicled as "fishy," "pig-pen," "cucumber," and the like, have been reported as affecting, at one time or another, the water-supplies of most of our towns.

There is good reason to suppose that these complaints will continue as long as water, which on standing has lost much of its dissolved oxygen and has become stagnant, is exposed to our burning suns and allowed to rise to a temperature of 70° and upwards, in uncovered reservoirs. Either it should be covered, so as to exclude light, and kept cool, or, if its temperature is allowed to

rise above 70° and it is exposed to the sun, it should be charged with air and kept moving.

Storage and Subsiding Reservoirs.—The development of aquatic growth, and the nauseous tastes and smells arising from its decay, have probably had a discouraging influence upon the construction of large subsiding reservoirs in our own country. In many cities, as in New York and Philadelphia, the small storage capacity has been for years the cause of most serious apprehension. The new works now in progress in connection with the Croton Aqueduct will, it is hoped, overcome this danger, so far as New York is concerned. I noted, however, with great interest, that Mr. Worthen, in the course of his examination before the commission charged with providing a more abundant supply for the metropolis, made the significant remark, in relation to the great new reservoir at Quaker Dam, which will hold 3,600,000,000 gallons, that *stagnant water would not keep.* In England, this difficulty is sometimes, though rarely, encountered. I asked Mr. Wood, the City Engineer of Leeds, whether the English reservoirs are injuriously affected by vegetation. He said that trouble from this source seldom occurred, but when it did occur it was owing to the growth of the American weed. The particular kind of weed he referred to was not so common as its name would appear to indicate, and I never saw it. The great benefit due to storage and subsidence was strikingly exemplified in the case of the city above referred to. Its water-supply is taken from the drainage area of the small river Washburn, at a distance of about ten miles from the city. On this stream are located three impounding reservoirs, and their waters are carried by gravity into the Eccup Reservoir, an artificial lake a mile long and holding 1,400,000,000 gallons. This supply, without addition, is adequate for the consumption of 10,000,000 gallons per diem for nearly five months. But this safeguard is only a part of the advantage due to the large size of the reservoir. For the water is made to enter at the bottom near the great dam forming one end of this artificial lake, and fifty-two feet below the surface. It then travels the entire length of the lake and is taken out by a bell supported on masonry piers, the lip of the bell being 15 feet below the surface and 23 feet above the bottom. During its months of

passage, not only nearly perfect sedimentation of earthy particles occurs, but, by a process of natural oxidation the peaty color is bleached out. Though such is the case, all the water is subsequently filtered, seven filter-beds being adequate, and finally stored in covered reservoirs. These reservoirs are made with inverts of masonry, upon which walls are built, capped by arches, the latter being covered with earth and handsome lawns.

It is not improbable that the difficulties, which we encounter in America from the long-continued heat of summer, may lead to remedies appropriate to our peculiar needs. I have already alluded to the advantage derived from first bringing the percentage of oxygen to the highest possible point, in delaying or preventing that condition of oxygen-poverty, with its resultant growths, which we recognize as stagnation. During the warmer months, reservoirs could be provided with such a covering as might be thrown out of use when winter came on with the accompaniment of crushing weights of snow. I saw at Manchester, Bradford, Buxton and many other towns in England, subsiding reservoirs arranged to effect a subsidence of the sludge or coagulum, which is produced when town sewage is treated with lime. These reservoirs are built with vertical partitions, so that the water flows over the top of the first and under the bottom of the second, and over the top of the third, and so on through sometimes as many as twelve compartments. Where the town sewage does not contain dye-stuffs, as at Buxton, the water coming out of the last compartment is frequently as sparkling as spring-water. The construction of subsiding reservoirs for water-storage in a similar manner, would facilitate cleansing, inasmuch as the greater part of the silt would be deposited in the first and second compartments, and a constant onward movement of the water without a disturbing current would be obtained, permitting of subsidence, while at the same time preventing stagnation.

Filtration.—Up to the present time no material has been found, which is practically available for filtration on a large scale, except fine sand. Sponge, coke, animal and wood charcoal, porous brick, carbide of iron, spongy iron, and many other materials have been tried, but with the result as above stated. When metallic iron is used excellent results are obtained, through its chemical action as

a carrier of oxygen to the organic matters which are thereby oxidized and destroyed, but the water even then must be subsequently filtered through sand.

Until quite recently, it has been supposed that the main benefit of sand-filtration is in the removal of suspended mud and dirt, the amount of organic impurities thereby removed being small. But since Pasteur discovered that the micro-organisms, which are supposed by some to be the specific germs of disease, may be completely arrested by filtration through a thin porous plate, a great revolution of opinion has been effected. In his report for the month of May last, Dr. Frankland states that the unfiltered Thames water yielded by the method of gelatine-peptone culture, 4,800 colonies of microbes per cubic centimetre of water. After passage through sand-filters at Chelsea, it yielded only fifty-nine colonies, and through those of West Middlesex only nineteen colonies. This is indeed astonishing, and the more so when the remarkably pure water in the deep chalk-wells of Kent yielded eight colonies, and the same water by the time it reached its point of supply had increased in its number of micro-organisms, until 101 colonies were obtained in the culture liquid.

At the present time American engineers regard it impracticable to introduce the English system of sand-filters, on account of the great expense of operating them. This has been variously estimated at from $2.50 to $5 per day for each million gallons filtered, exclusive of first cost and interest. Such being the case, I need not go into a statement of the reasons why the few which have been actually brought into use in this country have been so little successful. The conviction appears to be generally entertained that American ingenuity must discover some method by which mechanical arrangements may take the place of the cumbrous English system, and dispense with the very considerable manual labor required in cleansing. Many contrivances have been brought forward, but they are crude, or have complicated systems of pipes for reversals of the current, or are wasteful in the use of filtered water for cleansing. Recently, however, an extremely simple device has been proposed, which is yielding excellent results. As is well known, the efficient part of a filter-bed is the top layer of sand, which need not be more than two feet in thickness. At Poughkeepsie, on the Hudson River, this two feet of sand rests on four

feet of gravel and stone, which are provided merely to support the sand and to afford channels for the filtered water to drain away. This gravel and stone are replaced in the device I have alluded to, the National Filter, by a system of double pipes which are perforated and the annular space between the perforated pipes filled in with fine quartz gravel. The filtered water runs out through these double pipes, while the sand is arrested. By another simple arrangement the manual labor requisite to clean the deposit of dirt from the upper surface is dispensed with. A system of perforated pipes is laid at a distance of six inches below the surface. When it is necessary to cleanse the filter a reverse current of filtered water is sent upward under pressure through these pipes and the impurities are washed off and floated away.

Damage by waste.—The statistics of water-distribution in our American cities show that from one-third to one-half of the water is wasted, not used. Less importance seems to be attached to dirty and unwholesome water, provided there is enough of it, than to controlling dishonest waste and expending the money thus saved in improving the quality of the supply Until such waste is stopped by metering and fines, there will be little popular sympathy or support for movements intended either to purify and filter the water at present used, or to go ninety miles to get water, one-half of which will subsequently be thrown away.

PROPOSED IMPROVEMENTS IN THE PORT OF HAVRE AND THE ESTUARY OF THE SEINE.—In order that the French ports may hold their position against their rivals on the Continent, the entrance of the Seine must be improved. With this object the following works are proposed: To prolong the dikes as far as Houfleur, to close by a mole the two channels which exist near Villerville, and thus to place Havre at the end of a narrow neck between the sea and the great estuary of the Seine. The Seine dikes would terminate at Rouen, and the channel of the river would remain fixed under the jetties of Houlfleur.—*Mem. de la Soc Ingén Civils, April, 1886.*

A NEW ODONTOGRAPH.

BY GEORGE B. GRANT, Boston, Mass.

My object is to explain the construction and operation of an odontograph, or rather, an odontographic method, which is not only arranged with special reference to convenience and ease of operation, but which is also as accurate as can be desired for all ordinary purposes of construction or drafting.

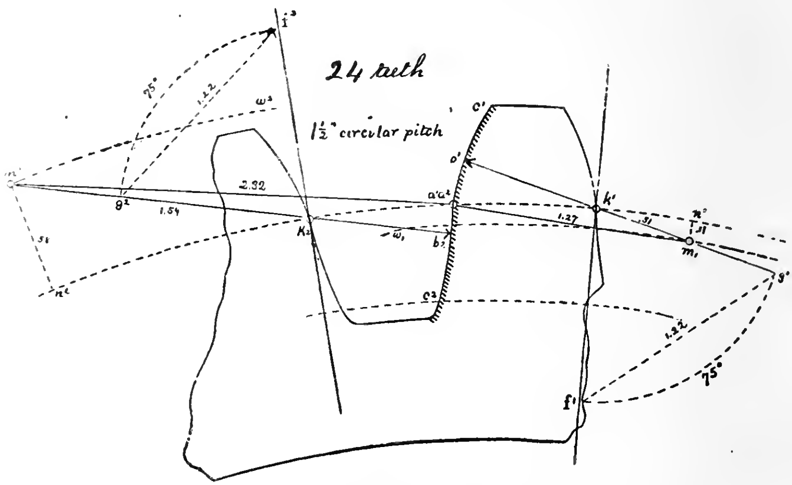

FIG. 1. Willis Odontograph.

In my business, which is specially devoted to the construction of gearing, I formerly had frequent occasion to make use of the well-known Willis odontograph, which has practically been the only one in use for thirty years past.

When using this instrument, the method, as illustrated by *Fig. 1*, is as follows: (1.) The pitch circle is divided off for the pitch points. (2.) A radius is drawn to the pitch circle. (3.) The instrument is laid on the radius. (4.) The positions on the instrument, of the centres, are found by the use of a table. (5.) Circles are drawn through the centres. (6.) The tooth-curves are all drawn in from centres on the centre-circles.

It occurred to me, after wading through this process many times, that much of the work could be got rid of by calculating the

results of the process and arranging them in a table. The real object in view, in the process outlined above, is to get the positions of the circles that contain the centres, and the lengths to set up on the dividers when drawing the tooth-curves. I constructed and for a time used a table giving the distances $m^1\ n^1$ and $m^2\ n^2$ of the circles of centres, and the radii $a^1\ m^1$ and $a^2\ m^2$ for the tooth curves. The result was that much of the labor was avoided and the accuracy of the result greatly improved. It is a work of great skill to so handle the Willis instrument that the same example will give the same result when the operation is repeated, while the use of the table will give uniform results without trouble. The

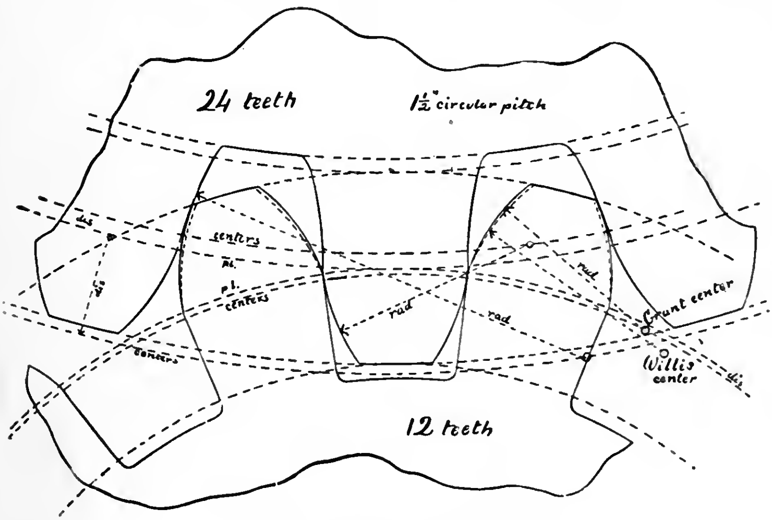

FIG. 2. Epicycloidal Teeth.

two methods are identical as to the position of the resulting tooth-curve.

It afterwards occurred to me that the process would be in no way lengthened, or its difficulty increased, if the centres, found by the use of the table, were the centres of the circles which most nearly coincide with the true curves, instead of the Willis centres of the osculatory circles at the centres of the curves, and this is the method here given and illustrated by *Fig. 2* and the Table I.

The method adopted for the construction of the table was a mathematical process, tested by graphical processes. I first computed the co-ordinates of the points of the true curve at the adden-

dum point and at the centre of the curve, then the co-ordinates of the centres of the circles that pass through these two points and through the pitch points, and then the actual lengths of the radii of the circles as well as the distances of the centres of circles from the

GRANT'S ODONTOGRAPH TABLE I.—EPICYCLOIDAL TEETH.

INTERCHANGEABLE SERIES.

From a Pinion of Twelve Teeth to a Rack.

NUMBER OF TEETH IN THE GEAR.		FOR ONE DIAMETRAL PITCH. For any other pitch, divide by that pitch.				FOR ONE INCH CIRCULAR PITCH. For any other pitch, multiply by that pitch.			
		FACES.		FLANKS.		FACES.		FLANKS.	
Exact.	Intervals.	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.	Rad.	Dis.
12	12	2.01	.06	∞	∞	.64	.02	∞	∞
13½	13–14	2.04	.07	15.10	9.43	.65	.02	4.80	3.00
15½	15–16	2.10	.09	7.86	3.46	.67	.03	2.50	1.10
17½	17–18	2.14	.11	6.13	2 20	.68	.04	1.95	.70
20	19–21	2.20	.13	5.12	1.57	.70	.04	1.63	.50
23	22–24	2.26	.15	4.50	1.13	.72	.05	1.43	.36
27	25–29	2.33	.16	4.10	.96	.74	.05	1.30	.29
33	30–36	2.40	.19	3.80	.72	.76	.06	1.20	.23
42	37–48	2 48	.22	3.52	.63	.79	.07	1.12	.20
58	49–72	2 60	.25	3 33	.54	.83	.08	1.06	.17
97	73–144	2.83	.28	3.14	.44	.90	.09	1.00	.14
290	145–rack.	2.92	.31	3.00	.38	.93	.10	.95	.12

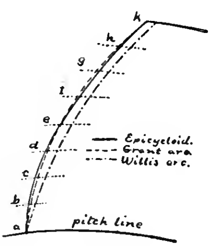

FIG. 3.

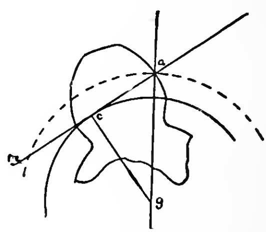

FIG. 4.

pitch lines. It is obvious that these circles are as close to the true curve as circular arcs can be made.

The improvement made in accuracy is illustrated in *Fig. 3.* The new arc crosses the curve twice, coinciding with it at three points, while the Willis arc leaves it at the pitch line and thence

runs entirely inside of it. The following table gives the errors of both arcs at nine points of a twelve-tooth pinion of a diametral pitch of unity, computed with great care to four places of decimals, or ten-thousandths of an inch. It is seen that the average error of the old curve is about six times that of the new.

	New Curve.	*Willis.*	
At *a*	·0000	+ ·0000	inches.
" *b*	+ ·0088	+ ·0175	"
" *c*	+ ·0091	+ ·0244	"
" *d*	+ ·0056	+ ·0283	"
" *e*	·0000	+ ·0288	"
" *f*	— ·0036	+ ·0297	"
" *g*	— ·0061	+ ·0308	"
" *h*	— ·0046	+ ·0342	"
" *k*	·0000	+ ·0397	"
Average	± ·0042	+ ·0260	

The greatest error of the new arc is at about the quarter point *c*, and for a tooth of a diametral pitch of unity, twice the size of the tooth of *Fig. 2*, this maximum error is as follows:

For	12	teeth	$c =$ ·009	inches.
"	20	"	$c =$ ·008	"
"	40	"	$c =$ ·006	"
"	100	"	$c =$ ·004	"
"	300	"	$c =$ ·002	"

The new curve is the most accurate, approximating most nearly to the true curve, at the point of the tooth, where accuracy is most needed, and where the Willis arc is most at fault.

Fig. 2 shows the two processes applied to a twelve-tooth pinion, the full arcs being by the new process and the dotted arcs by the Willis process. As the number of teeth increases, the accuracy of both arcs improves, until, for a very large gear either arc practically agrees with the true arc.

It may reasonably be claimed that the new arc is as near to the true curve as it is necessary to get, for hand and eye processes cannot appreciate a greater accuracy. It is doubtful if anything but the most delicately-constructed shaping engine could form a templet with a smaller error, for it is found in practice that templets constructed with the greatest skill by ordinary means, must be brought into shape by hand and eye processes, before they are

ready for use for the purpose of making gear cutters. The writer does not know of a purely mechanical process used in the construction of gear-teeth that will give closer results, except the Bilgram originating machine.

The Beale epicycloidal engine of the Brown & Sharpe Manufacturing Company will shape theoretically correct templets and templet gears with the greatest precision, the errors being all within a thousandth of an inch in magnitude, but, unlike the Bilgram machine, it has not as yet been applied directly to the shaping of the teeth of working wheels. But machines of this class can hardly

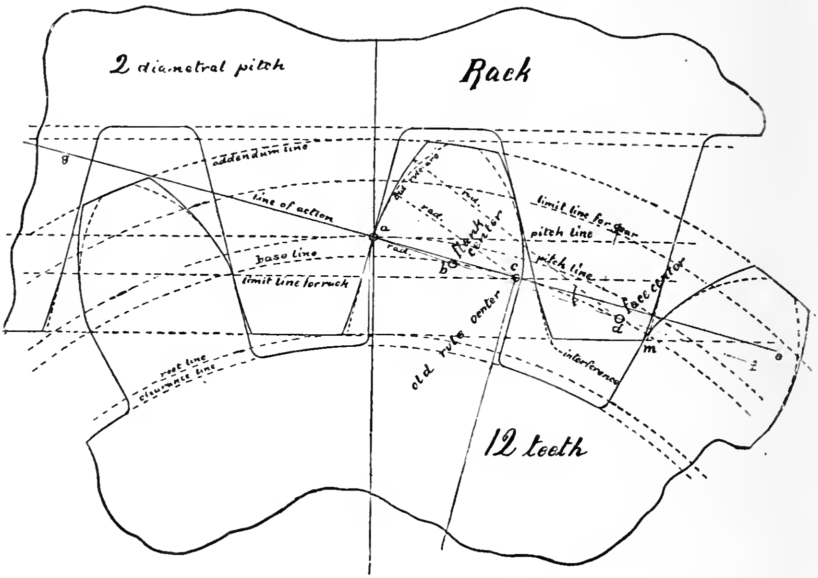

FIG. 5. Involute Teeth.

be compared with odontographs, as their expense puts them beyond reach for ordinary drafting or constructive purposes.

The principal application is to the interchangeable system of gear-teeth, but I have also applied it to the case, sometimes met with in practice, of teeth with radial flanks, not interchangeable. The upper number in each square of the Table II, is the face radius, while the lower is the centre distance. As shown by the table, most of the centres are inside the pitch line, some are on the line, while others, those having the negative sign, are outside of it.

A great advantage of the new method is that it can be applied

GRANT'S ODONTOGRAPH TABLE II.—EPICYCLOIDAL TEETH.

RADIAL FLANK TABLE.

FOR ANY POSSIBLE PAIR OF GEARS, NOT INTERCHANGEABLE.

One Inch Circular Pitch.

For any other pitch, multiply by that pitch.

NUMBER OF TEETH IN GEAR BEING DRAWN.		NUMBER OF TEETH IN THE MATE.											
Exact.	Intervals	12	13 14	15 16	17 18	19 21	22 24	25 29	30 36	37 48	49 72	73 144	145 rack
12	12	.64 .02	.64 .01	.65 .01	.66 .01	.67 0	.68 0	.69 -.01	.70 -.01	.71 -.02	.73 -.02	.74 -.03	.75 -.03
13½	13-14	.65 .02	.66 .02	.67 .01	.68 .01	.69 .01	.70 0	.72 0	.74 -.01	.75 -.01	.76 -.02	.78 -.02	.79 -.03
15½	15-16	.67 .03	.68 .02	.69 .02	.70 .01	.72 .01	.74 .01	.75 0	.78 0	.79 -.01	.82 -.02	.84 -.02	.84 -.03
17½	17-18	.68 .04	.70 .03	.71 .02	.73 .02	.75 .01	.77 .01	.78 .01	.82 0	.84 -.01	.87 -.01	.89 -.02	.90 -.03
20	19-21	.70 .04	.72 .04	.74 .03	.76 .02	.79 .02	.81 .01	.83 .01	.87 0	.90 0	.93 -.01	.96 -.02	.96 -.03
23	22-24	.72 .05	.74 .04	.76 .04	.79 .03	.82 .02	.84 .02	.87 .01	.91 .01	.94 0	.98 -.01	1.01 -.02	1.03 -.03
27	25-29	.74 .05	.76 .05	.79 .04	.82 .04	.85 .03	.87 .02	.92 .02	.96 .01	.99 0	1.03 -.01	1.07 -.02	1 10 -.03
33	30-36	.76 .06	.79 .05	.83 .05	.86 .04	.90 .03	.94 .03	.98 .02	1.02 .01	1.06 0	1.11 0	1.17 -.01	1.23 -.02
42	37-48	.79 .07	.83 .06	.86 .05	.90 .05	.96 .04	98 .01	1.03 .03	1.08 .03	1.14 .02	1.20 0	1.25 0	1.37 -.01
58	49-72	.83 .08	.87 .07	91 .07	.96 .06	1.02 .06	1.05 .05	1 10 .04	1 17 .04	1.24 .03	1.30 .02	1.43 0	1.58 0
97	73-144	.90 .09	.93 .08	.97 .08	1.01 .07	1.07 .07	1.11 .06	1.18 .06	1.28 .05	1.34 .04	1.47 .03	1.65 .02	2.03 0
290	145 rack	93 .10	.96 .09	1.00 .09	1 05 .09	1.10 .08	1.16 .08	1.24 .07	1.37 .07	1 50 .06	1.70 .04	2.12 .03	2.90 .02

GRANT'S ODONTOGRAPH TABLE III.—INVOLUTE TEETH.

INTERCHANGEABLE SERIES.

From a Pinion of Twelve Teeth to a Rack.

NUMBER OF TEETH IN THE GEAR.		FOR ONE DIAMETRAL PITCH. For any other pitch, divide by that pitch.			FOR ONE INCH CIRCULAR PITCH. For any other pitch, multiply by that pitch.		
Exact.	Intervals.	Base Distance.	Face Radius.	Flank Radius.	Base Distance.	Face Radius.	Flank Radius.
12	12	.20	2.70	.83	.06	.86	.27
13	13	.22	2 87	.93	.07	.91	.30
14	14	.23	3.00	1.02	.07	.95	.33
15	15	.25	3.15	1.12	.08	1.00	.36
16	16	.27	3.29	1.22	.08	1.05	.40
17	17	.28	3.45	1.31	.09	1.09	.43
18	18	.30	3.59	1.41	.09	1.14	.46
19	19	.32	3 71	1.53	.10	1.18	.50
20	20	.33	3.86	1.62	.10	1.22	.53
21	21	.35	4.00	1.73	.11	1.27	.57
22	22	.37	4 14	1.83	.11	1.32	.60
23	23	.39	4.27	1.94	.12	1 36	.63
25	24- 26	.42	4.56	2.15	.13	1.45	.70
28	27- 29	.45	4.82	2.37	.14	1.54	.77
31	30- 32	.50	5.23	2.69	.15	1.67	.88
34	33- 36	.57	5.77	3.13	.17	1.84	1.00
38	37- 41	.63	6 30	3.58	.19	2.01	1.16
44	42- 48	.73	7.08	4.27	.22	2 26	1.38
52	49- 58	.87	8.13	5.20	.26	2.59	1.70
64	59- 72	1.07	9.68	6.64	.32	3.09	2.18
83	73- 96	1.39	12.11	8.93	.42	3.87	2.90
115	97-144	1.92	16.18	12 80	.58	5.16	4.15
192	145-288	3.20	25.86	22.30	.96	8.26	7.30
576	289-rack	9.60	73.95	70.10	2.88	23.65	22.30

INTERFERENCE

FOR TWELVE TO RACK INTERCHANGEABLE SET.

Teeth In the gear.	12	13 14	15 16	17 18	19 21	22 24	25 29	30 36	37 48	49 72	73 144	145 ∞
Pitch.	Amount of the Interference.											
One in. cir.	.003	.007	.007	.007	.007	.007	.010	.010	.010	.013	.017	.020
One diamet'l	.01	.02	.02	.02	.02	.02	.03	.03	.03	.04	.05	.06

Interference always to commence at a point half way between pitch line and addendum line.

to the involute form of tooth as well as to the cycloidal form. The involute is superior to the cycloid, theoretically and practically, but the Willis process does not apply to it, and if drawn at all, it is generally by the ridiculously inaccurate method shown by *Fig. 4.* By this simple, but worse than worthless method, the line *a c* is drawn at an angle of 75½° with the radial line, and then the tooth-curve is drawn from a centre, *c*, at a distance *a c* of one-quarter of the radius. Nothing could be simpler, and it would be difficult to contrive anything further from the truth, for the result on a twelve-toothed pinion is shown by the dotted lines of *Fig. 5.*

The new method, as applied to the involute, is given by the Table III, and illustrated by *Fig. 5.* The base circle is first drawn at the tabular distance from the pitch circle, and then the faces and flanks are drawn in with the tabular radii, from centres on the base circle. The supplementary table shows the necessary correction, for interference, on the points of the larger gears.

POPULAR ERRORS IN METEOROLOGY.

By Cleveland Abbe.

[*A Lecture delivered before the* Franklin Institute, *December 17, 1886.*]

The Lecturer was introduced by Dr. Wahl, Secretary of the Institute, and spoke as follows:

The pleasure with which I appear before you to-night for the purpose of directing your attention for a short time to some popular points in meteorology, is greatly increased by the recollection of those eminent scientists, who in this city and even in this hall, long since expounded some of the most important laws previously unknown, the knowledge of which has gradually worked a revolution in our views as to the philosophy of atmospheric processes.

You will remember that it was to Benjamin Franklin himself that we owe the general promulgation of the fact that many of our Northeast storms move slowly along our Atlantic Coast from Georgia to New England. It was here that he drew the lightning from the skies and wrested the sceptre from the hands of tyrants." To Godfrey, we owe the sextant, and to Rittenhouse the establishment of our first observatory with accurate methods of observation, both astronomical and meteorological. To Bache and the

Girard College, we owe the invention of several meteorological instruments, the establishment of our only extensive set of hourly meteorological records in America, and an elaborate discussion of the observations whence many interesting general laws were deduced; finally, to Espy, an active member of this Society, born in 1785, in Washington County, Pa., modern meteorology is indebted for such a thorough study of the clouds, of their methods of formation and of the secret of the growth of storms, whether the smallest thunder-storms, or the grandest hurricane, as has made him eminently worthy to receive the title "The Father of Modern Meteorology." Redfield gave us the statistics of storms, but Espy the philosophy of storms.

Fifty years ago the FRANKLIN INSTITUTE appointed a permanent Committee on Meteorology; to that committee we owe the study of meteors by Sears C. Walker, the establishment of a State Weather-Service for the especial study of thunder-storms, the discussions that helped to perfect Espy's theory of the formation of clouds and rain, the especial investigation of the New Brunswick tornado, the Meteorological Observatory of Girard College; and I should weary you were I to enumerate the many other steps in the progress of our science that I would place to the credit of the influence, direct or indirect, of that active committee. Gradually, however, its members were drawn to Washington—Henry, Bache, Walker, Espy—in succession, and at the Capital of the Nation they continued to agitate the importance of the study and the possibility of a practically useful weather-service. From 1842 until his death in 1860, Espy was untiring in his advocacy, in season and out of season, of the possibility of storm predictions and his four *Meteorological Reports*, as published by the National Government, constitute a lasting monument to his industry and enthusiasm. Whoever shall write a comprehensive life of Espy will sketch the progress of meteorology from its ancient to its present, and apparently even its future, condition. While speaking of historical matters affecting Philadelphia and the FRANKLIN INSTITUTE, let me add that the great State of Pennsylvania has also, through Prof. Coffin, of Easton, given us that great work *The Winds of the Globe*, and to crown all, has given us William Ferrel, who has been, not merely the great expounder and developer of Espy's views, but in all mechanical questions has been to meteorology

what Sir Isaac Newton was to astronomy. Espy, Redfield, Coffin, and Bache did what they could by experiment and observation and general reasoning without mathematical assistance, but William Ferrel (born June 29, 1817, in the southern part of Bedford County, Pa , and graduated at Mercersburg), published, two years after Espy's death, a treatise *On the Movements of the Atmosphere*, which has been followed by a series of important studies in the mechanics of the atmosphere, that has made his name recognized throughout the world as the leading theoretical meteorologist of the present age.

When now I speak thus decidedly of great changes in our views and great progress in our science, I imply at once that the older views have ceased to be accepted, and that a new order of things has arrived. We Americans are so accustomed to accept great changes in political, social, commercial, domestic and financial matters that we expect such also in scientific matters. We are sometimes tempted to speak of change as something synonymous with progress, but unfortunately this is not always the case, for errors are daily planted in men's minds only to be uprooted by the progress of the Creator's great law of survival and evolution, changes therefore become progress only when they are guided by a higher intelligence. Happily, however, in all the physical sciences, and especially in meteorology, we may speak certainly of undoubted progress during the past thirty years—progress that is known as yet mostly to the special students only, and has not yet made itself felt among the mass of people who have had no opportunity to keep up with this advance, and to whom, therefore, matters remain very much in the same state of belief in which they were in our childhood.

But every race, like every individual, has gone through its childhood, and many of the ideas prevalent among us a few years ago will be found repeated over and over again in the early poetry of every nation since the dawn of human history; much of the mythology of the Teutonic and the Latin races dates from an early period of which we know but little except what is handed down to us in the Sanscrit literature of Persia and Northern India. To those early ancestors of ours, the sun was the Ruler of Heaven; the little clouds, white and fleecy, were his sheep, of which the herds gathered in the morning from the West, were, during the day, driven

to the Eastern horizon, where they disappeared in the evening, and whence in some mysterious way they returned the next day from underneath the earth, to begin again their wanderings to and from their pasture-fields. But the bigger clouds, dropping little showers as they passed along, were his herds of cows dropping refreshing streams from their over-charged udders, while the great clouds black and threatening, whence thunder and lightning and wind were sent forth, were his own angry messengers sent to punish the wicked in this world, or the bad angels of the Spirit World fighting against the good. Such thoughts as these, which we now call poetry, expressed all that they then knew of meteorology, *and how much more did our own nurses and parents know*, who, on the approach of a summer thunder-storm, huddled us children together in a dark room on a feather bed and told us His angry eye flashed in the lightning, and His warning voice spoke in the thunder.

The student of science cannot possibly allow these beautiful or sublime phenomena to play thus upon his emotions; he recognizes the fact that whatever of the æsthetic there may be in Nature, and he himself is awake to it at the proper time, yet it must be temporarily ignored, while he is severely studying the underlying laws, by virtue of which the grand and the beautiful have their existence. So the sculptor masters the secrets of the ghastly skeleton before he can cover it with flesh and beauty. No one who beholds a beautiful spectacular play, wishes, in the midst of his enjoyment, to be reminded of the machinery behind the scenes; no one who is carried along by the orchestra cares to think of the laws of acoustics; no one in the midst of an elegant dinner enjoys a rehash of domestic and kitchen troubles—so, many dislike the student to spoil their enjoyment and turn their attention from Nature to Nature's laws; many even deem it sacrilege, if for a moment we omit to associate with the storm, the idea of God's power, or with the rainbow the promise of His Fatherly watchful care; many of you would even tremble for my orthodoxy if I should assert that neither revelation nor science authorizes a well-founded faith in the efficacy of prayers for rain, or against storms. What I said a few weeks ago about the earthquake applies equally to the weather: "We know perfectly well that an earthquake may occur at any time, and at any part of the world, and that our fancied security is simply the expression of our hope that one may not come here at

present. We must go on cultivating land and building houses because these things must be done, earthquake or no; the only effect that our knowledge of our liability to earthquakes should have upon us, should be, to make us seek to diminish their destructiveness, first, by a proper style of building, and, second, by such studies as will enable us to predict the time of their occurrence." Precisely so with storms and drought, frost and heat, we know these things must come upon the just and the unjust; what we have to do is to foresee them, predict and provide against them. Who would repeat the prayer in the old Russian prayer-book?

> "Lord, God, give pleasant sunshine,
> To us and to the Lobenstein,
> And if others want things good,
> Let them ask for it, to suit."

I hope, therefore, the time is now at hand when a popular error that has existed throughout the world for ages in regard to meteorology, shall be definitely and permanently dispelled, and we shall come to see clearly that the Creator never in the least interferes with the perfectly regular working of those laws concerning the atmosphere that were originally established by Him;—after He had finished the creation, *He saw that it was good*—and it has remained so to this day. And yet the fact remains that it is good to pray for whatever we need—it draws us nearer to God—just as a child will ask its parents, if it has anything of the spirit of love and affectionate dependence, but always with the provision: "Thy will, not mine, be done—thou knowest best."

Let us then recognize that in general the atmosphere is governed by immutable laws, and seek for the forces that control it. Almost anyone of us here, at the present time, would naturally say, the heat of the sun is the most important factor, and yet, strange as it is, there are millions who to-day are studying the moon and stars, or rather, they are basing their every-day lives upon weather predictions, published in the almanacs made up sometimes several years in advance by means of ancient astrological principles, whereas the plainest teachings of the real science of meteorology go to show that the influence of the moon, the planets and the stars upon our atmosphere is wholly inappreciable. It is vain to shut our eyes to the fact that Wiggins, Vennor, Capen, Foster and others in this country, and the Shepherd of Banbury,

in England, have a hold upon the credibility of the masses wholly unjustified by the value of their predictions, and are actually doing more harm financially than would cover the cost of all the Government Weather Bureaus in the World. One of the incidental benefits of our own Weather Bureau may be said to be its influence as an educator of the people; showing that every department of science can be made to contribute to man's comfort when systematically treated. Of all the heavenly bodies, except the sun, it may be safely said that the moon is most likely to have some slight influence on our atmosphere, but every effort to demonstrate such influence has so signally failed, that we may say with an astronomer of 100 years ago: "The moon *ought* to have an influence on the weather, but it *hasn't*."

We have, however, in those little dark spots that appear on the sun's surface a suggestion that has been worked up and overdone by very many; thus we have one who stoutly maintains that the appearance of any special "sun-spot" enables him to at once predict a corresponding special storm or weather. This idea has been arrived at apparently by a complete violation of all laws of logic. Areas of stormy or cold, or hot or windy weather, are so frequent all over the earth, and spots on the sun are so frequent, that it is always possible to pick out a number of coincidences in time; and the style of logic that demonstrates a certain storm to be caused by a certain spot would equally well be applied to demonstrate that my body is warmed by the mass of hot coals in the fire-place, while my cold hands are due to one special coal that will not burn as brisk as its neighbors.

The sun's spots vary appreciably; in a general way, our observations show it to be highly probable that the total amount of spottedness, or total frequency of spots on the sun, is accompanied by a slight change in the general condition of the earth's atmosphere, by reason of which, when fewer spots are visible on the sun, we have slightly *higher* temperatures on the earth's surface as a whole, but slightly *lower* temperatures in the equatorial regions. Again, for the maximum of sun-spots we have a slight minimum in the barometric pressure of the atmosphere; and again, for a maximum of sun-spots we have a slight maximum in the amount of rain-fall; and corresponding with this, at the time of the maximum of sun-spots, there is a little more water flowing

down the rivers of the world. Again, with the maximum of sun-spots there is a slight tendency toward a minimum of lightning and a minimum of hail-storms. But all of these relations are very feeble; that is to say, the changes in the condition of the sun's surface are very slight; they produce effects only barely appreciable in the earth's atmosphere as a whole, and it is utterly illogical to conclude that there is any direct connection between special spots on the sun and special localities on the earth. In fact, these studies simply confirm the conclusion that all our meteoric phenomena depend upon the sun's heat as such, and that any slight variation in this, by affecting the general atmospheric condition, may alter the rain in one part of the world, at the same moment that it alters the temperature in another place, or the wind in a third locality. May we, then, not hope that the sun-spots will gradually cease to appear (as they are now often made to do by sensational writers), as the cause of some special change in the weather, and be left in peace to work out quietly the slight influence they may have upon our atmosphere as a whole.

A singular belief has been handed down to us from remotest ages, to the effect that the animals, in their natural state, know more about the future weather than does man himself, and this idea has apparently grown out of the study of the habits of migratory birds and hybernating animals, all of whom do really seem to foresee the approaching seasons at least in a general way; it certainly has required the best power of the speculative naturalists to explain how such birds, for instance, as the wild duck, or the swan, ever came to think of making their long annual flights. We see the Indian go from the seashore, and a marine diet, in winter, to the forests and flesh diet in summer (or we see the modern American reverse this process), and we are not surprised, as we attribute it all to the intelligence of human beings, the necessities of their organization and the stress imposed by the changes in the season. Why, then, ought we to be surprised to find that the modern naturalist says that the migratory bird similarly inherits a gradually increasing amount of knowledge from his ancestors, that he has intelligence as well as the human being, and that he has not yet reached the limit of his intellectual development any more than has the white man? The migrations and the hybernating habits are, therefore, the result of the experience and teachings of many

past ages, beginning with the glacial epoch, and producing a habit of life in an intelligent animal to which he persistently adheres. It is not necessary to suppose that the Creator has given these animals a deeper knowledge of meteorology than has been given to human beings. He who consults the habits of the ground-hog, the crow, the spider, the wild geese, or the goose-bone, or the hundred other animals concerning which there are hundreds of rules in books of weather wisdom, is trusting to the intelligence of animals who are less intelligent than himself, and is neglecting to cultivate those faculties and habits of observation and reasoning with which his Creator has endowed him for the very purpose of getting at the mysteries of Nature and utilizing her powers to his own benefit. In other words, the meteorologist would say there is scarcely any truth in the idea that all these mute creatures have for self-preservation been fitted with what is to us an unknown sense, informing them of minute changes in the atmosphere long before the coming of the danger. They have either acquired their habits, as other intelligent creatures do, from experience and reason, or they are wholly guided by natural causes beyond their control.

The case of the Rocky Mountain Locust is an instance well calculated to illustrate this latter principle, *i. e.*, that natural causes sometimes direct every step. This "pest," after its last moulting, finds itself feeding in or near its native fields on the tender vegetation near the ground. Every day as the sun rises, after the dew is dissipated, it finds the atmosphere about it growing hot and dry and soon also its own moist tender wings become stiffened. There results on its part a nervous irritability which can be gratified best by active flapping of its wings, so that without any other profound instinct or intention on its part, it is carried upward above the ground to cooler, moister air, where strong northwest winds carry it rapidly southward, even to the Gulf of Mexico. Therefore, its migration into a region where rich pasture-lands await it, is not due to any superior knowledge on its own part. The eggs hatch out in these southern regions at a season of the year when strong southerly winds are more frequent, and thus the young locusts are by these carried back toward their starting place, without the intervention of instinct or inherited knowledge, but by causes beyond their control.

What is true of the animals is still more plainly true of vegetables, so that in fact nearly all the rules for weather prediction founded on the behavior of plants, such as the contracting of the down of the dandelion, the closing of the pink-eyed pimpernel, or of the convolvulus, in the day-time, or the gathering of dew on stones, or the falling of soot in the chimney, are all simply so many hygroscopic phenomena, and a well-made hygrometer, as used by meteorologists, will give more accurate indications than any of these natural objects.

Another erroneous idea, very widely prevalent, is shown by the tendency to explain this or that phenomenon as being due to atmospheric electricity or possibly to ozone. Both of these subjects have thus far eluded the attempt to observe them satisfactorily; we have, indeed, so-called records of electricity and ozone, but it is safe to say that with very few, if any exceptions, we have thus far been unable to interpret these records, and demonstrate that we have been really observing a purely atmospheric phenomenon, hence, I rate as a popular error, the frequent quotation of these as an active cause of meteorological phenomena.

We have many of us been accustomed to speak of the delightful influence of a summer thunder-storm in clearing and cooling the air, and it is true that cool clear air does frequently follow these storms. We are, however, here in danger of confusing cause and effect. A certain class of thunder-storms is not generally followed by cooler air; that is to say, any cooler than it would have been without the storm, while another large class is followed by a decided fall in temperature. In these latter cases, if I am not mistaken, the underflow of cooler air contributes so largely to the existence of the storm that at first sight one would say that the refreshing cooling of the air is the cause and not the effect. But a truer philosophy would show that uprising warm moist-air has caused both the inrush of cool air and the thunder-storm, so that the two latter do not stand to each other at all in the relation of cause and effect.

Many efforts have been made in this country to show that the destruction of our forests has affected our climate, and many instances are quoted to prove that the growth of forests on our treeless prairies has already materially modified the local climate—to neither of these views can I give my assent, and still less to the

theory advocated by some that the extension of telegraph and railroad lines has so affected the distribution of the electricity that more rain now falls in some localities than before. Of all such propositions, the weak point consists in the fact that we have not enough observations of rain-fall and temperature properly comparable with each other to justify any conclusion whatever. So variable is our climate, that a change of temperature of several degrees Fahrenheit, or a change of five per cent. in the average rain-fall could only be decided by comparing the average of 100 years of observation with the average of another 100 years taken before, or afterwards, under precisely similar circumstances. The mistakes in this respect have often arisen from an overweening confidence in one's memory. The oldest inhabitant confidently states that this is the coldest winter he ever knew; the leading newspaper reporter interviews him, and there appears a double-leaded article, with heavy head-lines: "Coldest Winter on Record. Decided Secular Changes in the Climate. Interesting Reminiscences of the Olden Time." The children and everybody read it, and become firmly convinced that the climate has changed, whereas the whole thing is based on the fallible memory of one man and the ready business-talent of another, and the truth is that, so far as our records go, whether of rain-fall, or temperature, or animal, or plant life, all things remain as they were in the days of our fathers; at least, so far as the atmosphere is concerned; a proviso that I insert because we are gradually getting proof of the occurrence of local changes of climate, consequent upon slow changes in elevation above sea-level.

If I have touched upon a few wide-spread popular misconceptions in regard to my science, I have still to take up a long list of questions frequently put to me and showing general, if not popular, errors widespread among this most intelligent nation; for instance, "Is the whirling-storm called hurricane, cyclone or tornado, caused by the friction between two great horizontal currents of air like the little whirls we see immediately behind a bridge pier in the middle of a river?" to which I answer, No! That was Dove's theory, but the meteorologists of to-day ascribe the tornado and cyclone to an uprush of air under one or more clouds, and the whirling is inevitable when the lower air rushes together from all sides to fill the place of that which has ascended. And here I

would call attention to an erroneous use of the word cyclone confined to some of the newspapers in this country, and which will, I hope, not be perpetuated, since many of the most reputable papers have already returned to a proper use of the word; the terms cyclone and hurricane should be applied to large storms only and the term tornado be restricted to those small and violent storms in which the up-draught through or around a central nearly vertical cloud or spout is the most prominent feature next after the terribly violent and destructive winds.

Again; among my questions is this:

"What is the special cause of the regular equinoctial storm?"

I am sorry to say that I know no "regular equinoctial." An old writer says, "Ye wind hath been noticed to be very tempestuous at ye time of ye equinoxes." All over the world it is a favorite habit among mankind to find a name, or a proverb, to suit every striking weather item: thus we we have a Sunday rain, a Michaelmas thaw, an equinox storm, a dog-day heat, etc. These names, however, are only names and prove nothing as to the reasons underlying the phenomena. With the changes of the sun's position and the consequent distribution of hot and cold air there come alike to old England and New England, months of stormy weather—the storm that appears next before or after the 21st of March, or the 21st of September, is dubbed the equinoctial of that year, but the name does not give the storm any other peculiarity. The frequency of storms is about the same for several successive weeks and one is as likely to occur on any other date as the date of the equinox.

Again; why is there less rain-fall caught in gauges high above the ground than in those on the ground. Do the drops grow as they descend?

The drops rarely grow after they have so nearly reached the ground, although they do grow as they descend through clouds of fog.

There is really the same amount of rain-fall at 100 or fifty feet altitude as on the ground; the fault is in our rain-gauge, which is exposed to stronger winds when set high up, and to almost no wind when flush with the ground. The stronger winds deflected around the gauge carry the drops to one side, and hence the higher gauge catches less than the lower one.

Among the experiments elucidating this principle are some made on your shot-tower, by Bache, fifty years ago, that have lately come to be more fully appreciated.

Again, why is it colder on a mountain-top near the sun ?

It is a very common error to forget that everything—our own well-clothed bodies included—is giving out heat rapidly by radiation, and that the maintenance of any pleasant temperature is due to the fact that the loss by our own radiation is equalized by an equal gain through the absorption of the radiation from other substances. But this latter is wanting in the case of objects on the summits of mountains, which, therefore, cool rapidly and stay so.

Someone asks, "Why do all signs fail in dry weather?" and "Why are Signal Service predictions of rain specially erroneous during droughts?" There are probably several reasons for this, some meteorological, some subjective. During droughts, one generally sees clouds forming during the morning hours, as the ground becomes warmer and warmer, showing that there is moisture in the air, but that it is slightly less than needed to form rain. In this delicate balance between conditions favorable and unfavorable to rain, the predictor needs, but has not, observations of the conditions prevailing in the atmosphere at large, as well as those prevailing at the surface of the earth. The absence of the necessary knowledge, therefore, increases the chance of an erroneous prediction. There is, moreover, a slightly subjective or personal consideration, namely, being aware of the existence of the drought and the great desire for rain, he is liable to yield to the desire we all feel to say something pleasant, or to predict that which will be most agreeable if it occurs; thus, the hope that it may rain, colors his predictions, so that between the two phrases, "fair weather" and "fair weather, possibly followed by light local rains," he is likely to adopt the latter as his prediction. The farmer who receives the latter sees the clouds gathering, and when the local thunder-storm passes by leaving him dry, but wetting some distant region, in his disappointment he calls the whole a failure; whereas the occurrence of even that slight local rain in a limited region has been for the Signal Service predictor a complete verification, but the clamor of the thousands who did not receive the rain, overpowers the quiet rejoicing of the hundreds who did receive it.

Finally, it may be considered as a popular error that the people should *expect* the Army Signal Office to make perfectly correct local weather predictions thirty-six hours in advance for their benefit. That this is expected, we know by the grumbles we hear when a failure is announced. There even seems to be a growing disposition to look to the Signal Office for general weather or climatic predictions several weeks in advance of the season. Such predictions have been made in a few other countries, but when we consider the special methods that have been invented for that purpose, you will realize how very unsatisfactory such predictions may become. Thus, suppose we have for Philadelphia 100 years of daily weather records, and find that January 1st has during these 100 years been rainy ten times, snowy twenty times, fair—namely, neither rain nor snow—seventy times, then we should naturally predict for next New Year's Day fair weather, as the chances are in favor of that. But, after all, the favorable probability is too slight to be of much value. In the present state of our knowledge, these predictions will probably not be verified one-fourth of the time, and a person will do just as well to regulate his business without them. This latter conclusion I have heard sometimes made in a carping way with reference even to the well-known daily weather indications of the Signal Office; but this, I am sure, is altogether too sweeping, and nothing could be more erroneous than to condemn the great work of that office because of an occasional, or even a frequent failure, since by general consent, and by actual numerical data made up from the returns of hundreds of independent observers throughout the country, we know that those who from day to day regulate their business by its predictions find great profit therein.

However, I am by no means sure that detailed long range weather predictions would be very agreeable or profitable—"sufficient unto the day is the evil thereof." What would you do, my hearer, if you knew exactly what the weather is to be hour by hour for this next coming year. Would you be able to pick out the best day on which to plough, or sew, or reap? On *this* day the prediction gives you fair weather; will you plant at once, knowing that the prediction says heavy frosts on *this* day three weeks later, just in time to kill your young crops? Will you reap to-day because the predicted weather is highly favorable, knowing

that before half of that crop can be gathered into your barns the predicted hail-storm will be upon you? As nearly as I can see, he who should perfectly foreknow the weather would find himself at every step confronted by some approaching dilemma, some inevitable disappointment or loss; and shrinking, as we all do, from such events, he would sit down in despair and do nothing at all. In a general way, it is true of the weather, as of anything else, that an All-Merciful Father hides the future from us so that we, in our ignorance and helplessness, may labor on, full of hope that things may not turn out so bad after all.

And yet, so confident am I of the great future development of man and of science, and so clearly do I see the wise provision by which *everywhere in Nature we find the right thing, in the right place, at the right time*, that I dare predict to-night *the time will come* when men shall be able to endure and utilize detailed weather predictions for months and years in advance; and when that time comes the prophet and his predictions will be on hand.

THERMODYNAMICS.

By Professor De Volson Wood.

During the past year, the writer published several articles upon Thermodynamics in Van Nostrand's *Engineering Magazine*, which were designed chiefly to explain some parts of Rankine's treatment as given in his work, on *The Steam Engine and Other Prime Movers.* These articles were somewhat discursive, due to the circumstances under which they were written, and, since the publication of that magazine has been discontinued, I now seek the pages of this Journal for the purpose of considering a few points more critically. The writings of eminent scholars show that the more abstruse parts of Rankine's thermodynamics are not easily understood, and in our own experience we have found his treatment in his *Steam Engine* more difficult than in his original papers. This is particularly the case in regard to his "second law," which Maxwell considered as "inscrutable," and other writers, even down to the present time, have considered it necessary to attempt an explanation of what Rankine really meant.* His *Steam*

* At least as late as 1885. Address before the Mechanical Section of the A. A. A. S., at Ann Arbor, Mich., *Science*, September, p. 212.

Engine being used as a text-book, the meaning ought not to remain ambiguous, nor be left in the condition described by a writer of repute when he states: "While Rankine, if referred to at all, only his very words are quoted, showing that their scope is not fully grasped." * It is possible that sufficient explanations exist in published works, but if so, we are ignorant of the fact, and for this reason contribute the result of our study in attempting to determine his essential meaning—the very scope of his words, hoping that the points which remain obscure may quickly be removed by others. We select for the beginning of our study the paragraph which we consider the most difficult, being Article 241 of the *Steam Engine*, which, for the convenience of the reader, we quote, as follows:

"THE SECOND LAW OF THERMODYNAMICS.—*If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any number of equal parts, the effects of these parts in causing work to be performed are equal.* * * * The symbolical expression of the second law of thermodynamics is as follows: Let unity of weight of a homogeneous substance, possessing the actual heat Q, undergo any indefinitely small change, so as to produce the indefinitely small amount of work dU. It is required to find how much of this work is performed by the disappearance of heat. Conceive Q to be divided into an indefinite number of indefinitely small parts each of which is δQ. Each of those parts will cause to be performed the quantity of work represented by

$$\delta Q \frac{d}{dQ} d U,$$

consequently the quantity of work performed by the disappearance of heat will be

$$Q \cdot \frac{d}{dQ} d U, \tag{1}$$

which quantity is known when Q, and the law of variation of $d U$ with Q, are known."

We find, upon investigating this quotation, that no mention is made of certain essential principles, without which *the analysis cannot be established.*

* Van Nostrand's *Engineering Magazine*, 1879, p. 337.

Since the symbolic expression is a representation of the law, it may be used in explaining that law; and the law—if understood—may be used in explaining the analysis. The author, in speaking of the change, says: "Let the substance undergo any indefinitely small change;" from which one might infer that the change was arbitrary, but we will show that expression (1) is correctly produced only when the change is made according to a definite law—which law is *that of constant actual heat in the substance while doing work.* This is vital, and hence should, for the benefit of the student, have been mentioned. In a text-book, the student naturally expects to find the statement of principles preceding the analysis upon which the latter is founded; or, at least, in close proximity thereto, but in this case he will find the principle just referred to several pages in advance, near the latter part of Article 245, where it says, "It is to be observed, that the function U, representing the work performed by the kind of change under contemplation, is first to be investigated as if the temperature were constant." Work is performed by this substance only by enlarging the containing vessel, so that if v be the volume, the elementary charge will be $d\, v$; but "the change under contemplation" referred to in the preceding quotation, may include a change in temperature and pressure as well as of volume, in which case, it must be observed that the function is *first* to be investigated as if the temperature (or actual heat) were constant.

The uninitiated may suppose that $\delta\, Q$ is necessarily different from $d\, Q$, but such is not the fact, as is shown by Rankine's use of it in his original papers, where the expression is written:

$$d\, Q \frac{d\, P}{d\, Q}\, d\, V,$$

which is equivalent to

$$d\, Q\ \frac{d\, (d U)}{d\, Q}.$$

Moreover, as will appear in the sequel, if $\delta\, Q$ be different from $d\, Q$, then $\delta\, Q$ cannot properly be written as it is without making a partial solution of the problem, and is nearly equivalent to a complete solution of that part of it; for the operation by which Q is obtained in expression (1) is the same as that by which $\delta\, Q$ would be obtained from $d\, Q$, still assuming that they are different, but if

different, it is certainly correct to reduce δQ to that of $d Q$, so that the expression

$$d Q \frac{d}{d Q} d U$$

will be correct if the former is. The mathematical operation of deducing expression (1) from this consists of an integration, thus

$$\int d Q \frac{d(dU)}{d Q} = Q . \frac{d^2 U}{d Q} \tag{2}$$

but this is correct only when $\frac{d^2 U}{d Q}$ is independent of Q. This fact is vital in the operations of the calculus, but we will illustrate it by a special case. Let it be proposed to find the area of a curve referred to polar co-ordinates. Proceeding as above, we conceive the area to be divided into indefinitely small parts, each equal $d A$. Conceive the angular space to be divided into an indefinite number of small parts, each $d \theta$, then will the area of one part be

$$d \theta \frac{d A}{d \theta},$$

and hence for the angular space θ, the area would be

$$B = \theta . \frac{d A,}{d \theta,}$$

in which the last operation is equivalent to integrating the former expression considering $\frac{dA}{d \theta}$ as independent of θ. Now, this result is correct when $\frac{d A}{d \theta}$ is independent of θ; or, more generally, when it is constant. It is not generally true. For instance, the general expression for $d A$ is

$$d A = \tfrac{1}{2} \rho^2 d \theta,$$

which, substituted above, gives

$$B = \theta . \tfrac{1}{2} \rho^2 = \tfrac{1}{2} \rho^2 \theta$$

which is the area of the sector of a circle whose angle is θ, but for no other curve. The process, therefore, by which the value of B was found, is not general; it is correct for the circle, because $\frac{d A}{d \theta}$ is independent of θ.

If the angular space be divided into indefinitely small parts by circular arcs, then we would have

$$B = \int\int d\,\theta\,\frac{d^2 A}{d\,\theta} = \theta \int \frac{d^2 A}{d\,\theta}.$$

But

$$d^2 A = \rho\, d\,\theta\, d\,\rho;$$

$$\therefore B = \theta \int \rho\, d\,\rho = \tfrac{1}{2}\,\rho^2\,\theta;$$

as before, when $\frac{d^2 A}{d\,\theta}$ is independent of θ, as it is in the case of the circle.

In order to show more definitely the signification of $d^2 U$, let p be the pressure upon the inside of a vessel containing the expanding substance, and $d\,v$ the amount of increase of the volume; then if v be an independent variable, p, being dependent upon v, we have

$$dU = p\,d\,v;$$

$$\therefore d^2 U = dp\,d\,v$$

and expression (1) becomes

$$Q.\frac{d\,p}{d\,Q}\,d\,v. \tag{3}$$

Still further, it is more convenient to speak of temperature than of actual heat. Actual heat, or total actual heat, is simply the heat energy which remains as heat; it is called *sensible heat*. It is not the heat absorbed by a body. Thus, in changing water to steam, a large amount of heat is absorbed which is not sensible, being 966 thermal units for one pound of steam generated, the temperature remaining constantly at 212° F. Q does not include latent heat. The sensible heat from the supposed condition of total privation of heat, varies directly as the absolute temperature from the same zero. Equal quantities of *sensible* heat in a fixed weight of a substance, correspond to equal measurements on a scale of temperature, so that we have

$$Q : Q' :: \tau : \tau',$$

or

$$Q : d\,Q :: \tau : d\,\tau,$$

and expression (3) becomes

$$\tau\,\frac{d\,p}{d\,\tau}\,d\,v \tag{4}$$

The pressure is some function of the actual heat, or

$$p = f\,(Q)$$

and hence

$$\frac{d\,p}{d\,Q}=f'(Q)$$

may contain Q; or

$$\frac{d\,p}{d\,\tau}=f'(\tau)$$

may contain τ. To illustrate, it does not contain τ for the perfect gases, for then we have the well-known relation,

$$p\,v = R\,\tau;$$

$$\therefore \frac{d\,p}{d\,\tau} = \frac{R}{v} \tag{5}$$

considering v as constant. But for imperfect gases, accepting the form given by Rankine and Regnault, we have

$$p\,v = R\,\tau - \frac{a}{v} - \frac{a_1}{v\,\tau} - \frac{a_2}{v\,\tau^2} - etc.;$$

$$\therefore \frac{d\,p}{d\,\tau} = \frac{R}{v} + \frac{a_1}{v^2\,\tau^2} + \frac{2\,a_2}{v^2\,\tau^3} + etc. \tag{6}$$

which is a function of τ. Since the analysis is not restricted to perfect gases, but, as the sequel shows, includes imperfect ones, we see that

$$\frac{d^2\,U}{d\,Q} = \frac{d\,p}{d\,\tau} d\,v = f'(Q) = f''(\tau),$$

is a function of Q or τ. How, then, can expression (1) be obtained from that just preceding it? Or, what is the same thing, how can the reduction in equation (2) be correct? It cannot, unless $f'(Q)$ can be maintained constant during the expansion. This can be done by supplying heat to the substance from an external source; and this is what is actually done, or conceived to be done, during this operation. If a gas expands, doing work without heat being supplied to it, the temperature will fall; or, if compressed, under similar conditions, the temperature will rise; but by supplying heat, the temperature may be maintained constant, and, when so maintained, the expansion is called isothermal. If the base of a cylinder be perfectly pervious to the passage of heat, and in contact with an indefinitely large source of heat at the actual heat Q, or temperature τ, then may the temperature of the substance be maintained constantly at that heat while the pis-

ton moves out any finite distance, say from v_1 to v_2. Whatever be the means of maintaining the constant heat, the fact of a constant temperature must be conceived of in this part of the analysis, even when the expansion is indefinitely small. This is also a vital condition in the solution. We observe, then, that having written the identity

$$d\,p\;d\,v = d\,\tau\,\frac{d\,p}{d\,\tau}\,d\,v, \tag{6}$$

the latter expression is not permitted to be reduced to the former by the cancellation of $d\,\tau$, but a part of it, viz., $\frac{d\,p}{d\,\tau}$, is taken by itself and treated independently of the other terms of the expression before an integration is performed, its value being formed directly from the equation of the gas as shown above; or, as one may conceive, found by a direct experiment upon the substance, by finding the increase of the pressure $d\,p$ due to a very small change of the temperature $d\,\tau$, at some volume v. It is apparent that there is a great advantage in using the equation of the gas, when known, for it not only enables one to find directly the value of $\frac{d\,p}{d\,\tau}$, but also retains the value of v, so that the law of change dependent upon the volume, to be considered in a following operation, is retained in a form ready for use. The value of $\frac{d\,p}{d\,\tau}$ is a function of v, both for perfect and imperfect fluids, as shown in equations (5) and (6), but this fact does not prevent the integration of (2) in regard to Q or τ, for by the principles of the calculus, an integration may be performed in reference to one of the variables as if the other were constant. The expression $\frac{d\,p}{d\,\tau}$, or $\frac{d^2 u}{d\,Q}$, is a partial differential, being a value in which all the variables of the function are constant except p and τ; or, as there are only three variables in this case (p, v, τ), it is a differential coefficient, found on the condition that v is considered constant, although in reference to $d\,v$ it will be considered variable in a later operation. The partial differential is sometimes indicated by a parenthesis, thus, $\left(\frac{d\,p}{d\,\tau}\right)$, and some writers upon this subject introduce a subscript to show which variable is considered as constant; thus,

when v is considered constant, it may be written $\left(\frac{dp}{d\tau}\right)_v$. Clausius proposed to indicate this operation by placing the v as a subscript to d, thus, $\frac{d_v\, p}{d\,\tau}$, and Baynes writes the partial differential with a special symbol. Rankine says nothing about these forms, but when he distinguishes a total differential from the partial, writes the latter in the usual form, and places a period after d for the former. Thus, the total differential is written $d.\,H$, $\frac{d\,.\,\varphi}{d\,\tau}$, etc., as on pp. 310, 316, 320 of *Steam Engine*, the description of which appears to be contained in the words "represent respectively the *complete rates of variation*," near the middle of page 316. This is another instance in which the author has used a notation, not of the customary form, without any intimation of its significance until six pages after its first use. We also note in passing, that it is omitted in some places where its use is of vital importance, as in the expression $\tau\; d\; F$, page 310, which should be written $\tau\; d\,.\,F$ to conform with his own notation; since F is a function of τ and v, as shown by his analysis, and which is actually written in full in one of his original papers, thus:

$$d.F = \frac{d\,F}{d\,\tau}\,d\,\tau + \frac{d\,F}{d\,v}\;d\,v$$

While these omissions and tardy explanations may cause no difficulty to one versed in the science, they cannot fail to be vexatious to the student while acquiring this knowledge, and were it not for the fact that the author was a deep thinker, a strong writer and generally accurate in his processes and results (though there are exceptions) it would not pay to follow him; but, as it is, there is often a great satisfaction in studying his methods.

Returning now to the fundamental expression, which, for reasons already given, we write—

$$d\,Q\,\frac{d^2\,U}{d\,Q} = d\,Q\,\frac{d\,p}{d\,Q}\,d\,v = d\,\tau\,\frac{d\,p}{d\,\tau}\,d\,v,$$

and making $\frac{d^2 U}{d\,Q}$, or $\frac{d\,p}{d\,\tau}$, independent of Q, or τ, by making Q in the former and τ in the latter constant during the expansion of

the substance by supplying heat from an external source, the expression may be integrated once in reference to Q or τ, as the case may be, between limits. If $d\,W$ be the work, both external and internal, done by one pound of the substance due to the heat $d\,Q$ in expanding from v_1 to v_2 at the heat Q, then

$$d^2\,W = \frac{d\,p}{d\,Q}\,d\,v\,.\,d\,Q = \frac{d\,p}{d\,\tau}\,d\,v\,.\,d\,\tau \tag{8}$$

$$d\,W = \int_{v_1}^{v_2} \frac{d\,p}{d\,\tau}\,d\,v\,.\,d\,\tau \tag{9}$$

$$\int_{W_2}^{W_1} d\,W = W_1 - W_2 = \int_{\tau_2}^{\tau_1}\int_{v_1}^{v_2} \frac{d\,p}{d\,\tau}\,d\,v\,d\,\tau = (\tau_1 - \tau_2)\int_{v_1}^{v_2} \frac{d\,p}{d\,\tau}\,d\,v, \tag{10}$$

and the last term can be integrated when the equation of the gas is known, τ being treated as constant. Thus, for a perfect gas we have

$$p\,v = R\,\tau;$$

$$\therefore \frac{d\,p}{d\,\tau} = \frac{R}{v};$$

$$\therefore \int_{v_1}^{v_2} \frac{d\,p}{d\,\tau}\,d\,v = \int_{v_1}^{v_2} R\,\frac{d\,v}{v} = R\,log\,\frac{v_2}{v_1};$$

$$\therefore W_1 - W_2 = (\tau_1 - \tau_2)\,R\,log\,\frac{v_2}{v_1}.$$

A part of this analysis will be recognized as that of the elementary heat engine, and, although the analysis is simple, questions may be raised in regard to the physical conditions which it is not advisable to consider at this time.

Students ask—how can $\frac{d\,p}{d\,\tau}$ have a finite value, as in equations (5) and (6), when τ is constant?" It may be considered that $\frac{d\,p}{d\,\tau}$ is the rate of change of pressure per unit of temperature when the temperature is τ as in equation (6), and its value found when τ is variable; but having found the general value, τ may be maintained constant during expansion by a supply of heat, as already explained.

The last clause of the quotation from the text is, "Which quantity is known when the law of variation of dU with Q are known." This expression implies a relation between an infinitesimal dU and a finite quantity Q, which, mathematically speaking, is zero. The law of variation actually referred to, is between p and Q, or p and τ, the latter being used in practice, and should have been so expressed.

Another expression in the extract is: "It is required to find how much of this work is performed by the disappearance of heat." This is a difficult sentence to explain. The work referred to is $p\,dv$. The fact is, *all* of this work is supposed to be done by the disappearance of heat; and, as the sequel shows, more than this amount of work is done. This work, $p\,dv$, is entirely external work, like work done by a moving piston, but at the same time work of a molecular character is done, like the work of changing water to steam, or ice to water. The latter are extreme examples, but serve as striking examples of the character of internal work. In the case of ice, the internal work of fusion is thousands of times the external work, and the latter is negative; and in changing water to steam at 212° F. at one atmosphere the internal work is more than eleven times the external. There is always internal work in expanding an imperfect gas isothermally, but none in expanding a perfect gas. In the case of perfect gases, all "of this work is performed by the disappearance of heat;" and in the case of imperfect gases, not only all, but more "work is performed by the disappearance of heat." The implication of the author is that only a part of the work $p\,dv$ is performed by the disappearance of heat; but it is impossible for this to be generally true. We say *generally*, because if our statements above are generally correct there might be *exceptions* which would make the wording of the author correct, just as in algebra a quantity considered positive may prove to be negative. We assume that the author did not intend to use exceptional cases in establishing a general proposition, and are therefore forced to the conclusion that the sentence is logically defective—that it does not fully express the idea of the author—and hence we must seek for the idea in the context, or elsewhere in his writings, or from the essential principles of the subject. We observe, first, that if the words "of this" be expunged the reading will agree with other passages

of the text. Thus, just before expression (1) it reads, "the quantity of work performed by the disappearance of heat will be," which would be an answer to the demand above if the words "of this" were expunged. Three or four lines above the same idea is expressed, and again, on page 310 of the *Steam Engine*, it is repeated thus: "Then the work performed by the disappearance of heat is," and, as the sequel shows, all of these expressions include not only the external work, but internal also. By consulting his original memoir on the subject (*Miscellaneous Scientific Papers*, page 311), we find that the same language is used—"How much of this work is the effect of heat?"—but the analysis which follows shows that he considered that the work done by the disappearance of heat *exceeded* the external work, for he writes—

$$\left(Q\frac{d\,p}{d\,Q}-p\right)d\,v$$

for the molecular potential energy caused by the disappearance of heat.

It has been suggested that Rankine may have supposed that some other agent than heat, as electricity, magnetism, external or internal stress, or some unknown agent, was involved in doing the work $p\,d\,v$, but we do not find this view confirmed by his statements, nor by succeeding analysis, neither do we see how the effect of these agents can be separated by his process. If other agents than heat are working, changing the actual heat (or temperature) a small amount might change the energy of the other agents as well as the heat agents, unless, indeed, the action of the other agents are independent of heat, in which case there would be as little occasion for including them in the discussion as it would be to mention the fact of the moon's attraction upon the piston of the engine. It appears then that, so far as the text and context are concerned, no violence will be done to the author, or to the sense, if the words "of this" are cancelled—and they may, with propriety, be omitted. Still, we cannot satisfy ourself that the author used them inadvertently, or that the particular meaning which he wished to convey would be expressed without them. Even if not used inadvertently, the article bears evidence, as we have already seen, of having been hastily written; some of the essential ideas involved in the analysis not being mentioned; so that in this

case we assume that these words may be suggestive of some idea not yet assigned, the expression for which must be sought from a knowledge of the subject. Considering it in this light, we infer that it may mean—how much less work would be performed by the disappearance of an element of heat from the substance. A part of the work $p\,d\,v$ was done on account of the last element dQ of heat added to the substance, so that the idea is—how much of this work is due to an element dQ of the heat of the substance. But work destroys heat—causes an equal amount to disappear—so again we may say, how much of this work is performed by the disappearance of an element of heat from the substance. If the total actual heat of the substance be Q, it will, by an isothermal expansion, do the external work $p\,d\,v$; but when the actual heat of the substance is $Q - dQ$, it will do only a part of $p\,d\,v$ when

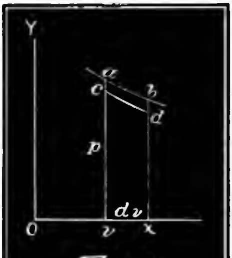

FIG. 1.

expanding isothermally—how much of it? Although the following analysis supports these interpretations of the sentence; yet it should be noticed that the expression "disappearance of heat" is not generally used in this sense. It generally refers—not to an element of heat permanently abstracted from the substance, but to the heat disappearing in doing work. Let $o\,v$, *Fig. 1*, represent the volume of one pound of the substance, $v\,a = p$ the corresponding pressure, and $a\,b$ the isothermal at the temperature τ. Let the expansion be $d\,v$ at the constant temperature τ, then will the external work done be

$$v\,a\,b\,x = p\,d\,v.$$

Let another isothermal $c\,d$ be drawn, representing a temperature $\tau - d\,\tau$, then would the external work be $v\,x\,d\,c$, and the difference between $v\,a\,b\,x$ and $v\,x\,d\,c$, or $a\,b\,d\,c$ represents the work done on account of the substance possessing the heat dQ above what it had

when it did the work $v\,x\,d\,c$; that is above $Q - dQ$. Or, to put it another way, it represents the loss of work due to the permanent abstraction of the temperature $d\ \tau$ from the substance during a given expansion. We have

$$c\,a\,b\,d = d\,p\,d\,v,$$

but p is a function of τ directly when v is constant, which fact, according to the notation of the calculus, may be indicated thus,

$$c\,a\,b\,d = \frac{d\,p}{d\,\tau}\,d\,\tau \cdot d\,v\,;$$

which, as an algebraic expression is equivalent to the preceding, and so appears at once by cancelling $d\,\tau$. But, if we now proceed as before, to operate upon $\frac{d\,p}{d\,\tau}$ by itself, we will find the rate at which the pressure increases per unit of absolute temperature. It is at this point that the analysis gets hold, so to speak, of the internal work, a fact which is the most difficult to realize, and the most difficult to explain in this whole analysis. *The heat absorbed while work is being done at isothermal expansion, must equal the entire work done*, and of this work all that is not external must be internal. It is the determination of the internal work which makes the problem difficult—since it cannot be measured directly, and can be determined only through the other measurable quantities of the problem. If the quantity of heat absorbed could be directly measured, we would thus, at once, determine the total work done, but this can be determined only by means of external work. The total heat absorbed under isothermal expansion can be determined by a method which we think is explicit and easily understood, and may be given later in this discussion; but at present we desire to follow, as closely as possible, the process of the author.

Admitting that internal work was done while the external work was $v\,a\,b\,x$, it will be apparent that some other element of internal work was done when the external work was $v\,c\,d\,x$, so that a slight change in the temperature of the substance not only affects the external work, but the internal also, and the latter is some function of the former. Admitting that the *rate of change* of the pressure per unit of temperature, when the pressure is p and temperature is τ, is determined by decreasing the temperature of the substance $d\,\tau$, and observing the corresponding diminution of pressure $d\,p$ at

the constant volume v, it will appear that this ratio is different for different gases, and that $d\,p$ will be greater for more imperfect gases for the same diminution of temperature. This being an abstruse point, we illustrate it by equation (6), which is

$$\frac{d\,p}{d\,\tau} = \frac{R}{v} + \frac{a_1}{v^2\,\tau^2} + \frac{2a_2}{v^2\,\tau^3} + etc.$$

in which the ratio $\frac{d\,p}{d\,\tau}$ is greater, the greater the values of a_1, a_2, etc., and is least for a_1, a_2, etc., equal zero, the latter giving

$$\frac{d\,p}{d\,\tau} = \frac{R}{v} = \frac{p}{\tau},$$

the value for perfect gases. The last ratio, $\frac{p}{\tau}$, shows that for perfect gases the ratio of the increment $d\,p$ to $d\,\tau$ varies directly as the total pressure to the absolute temperature.

(*To be continued.*)

THE MEIGS ELEVATED RAILROAD.

(*Report of* GEORGE STARK, C. E., *to the Board of Railroad Commissioners of the State of Massachusetts.*)

TO THE BOARD OF RAILROAD COMMISSIONERS OF THE STATE OF MASSACHUSETTS.

Gentlemen :—I had the honor to receive from you, on the 27th of October last, an appointment " as engineer under the provisions of Section 4, Chapter 87, of the Acts of 1884, for the purpose of examining the safety and strength of the structure of the Meigs Elevated Railway, so-called, in Cambridge, and the rolling-stock and motive-power used thereon, and of approving or disapproving the same." In pursuance of this appointment, I have since devoted a very considerable portion of my time and attention to the required examination, and beg leave now to submit this, my report:

The experimental section of Meigs elevated railway, which has been constructed at East Cambridge, is located on grounds formerly occupied by the Bay State Glass Company, and extends over Bridge Street to grounds of J. P. Squire & Co.

The structure has been erected wholly on made land, upon what was once the bed of Miller's River, and the mud underneath this made land is soft and deep. A rod of round iron, five-eighths of an inch in diameter, was easily forced down, near the structure, by one man, in my presence, its entire length, twelve feet, without striking hard bottom. The difficulty of building a secure single-post structure on this foundation has, of course, been much greater than it would have been on ordinary solid land. In addition to this natural difficulty, Captain Meigs has purposely introduced artificial obstacles in his track, for the purpose of showing that he can run his trains around curves of less radius and on grades of greater elevation than are now practicable on ordinary steam motor railways, and can safely pass horizontal or vertical angles in the track, of very considerable deflection. One of his curves makes an entire semi-circle, with a fifty-foot radius, on a grade of 120 feet to the mile, and another turns nearly a quarter circle with a radius of fifty feet, on a grade of 345 feet to the mile.

The construction of the track is simple, and the question of its strength and safety is easily determined. The entire structure consists of a single line of girders supported on a single line of posts; the two rails on which the bearing-wheels supporting the load run, being placed on the upper outside corners of the lower boom of the girder, and the two rails that resist the pressure of the horizontal driving- and guiding-wheels being placed on the other sides of the upper boom of the girder.

The problems to be solved are: (1) as to the strength of girder for sustaining a vertical load, represented by the fixed weight of the girder and the moving weight of the train passing over it, and for resisting the horizontal strains and twists that may come either from the grip of the driving-wheels or the momentum of the train, or the action of wind; and, (2), as to the strength of the posts, for sustaining the weight of girders and trains, and their stability and power of resistance against side-pressure, caused by momentum or wind blowing upon the side of the train.

The railway company has submitted to my examination extensive and thorough computations, made by engineers in their employ, to show the force of these various strains, and the amount and form and quality of material required in the girders and posts to safely resist and bear the loads and strains to which they are,

or may be, subjected. These computations show that the structure as built is, theoretically, of ample strength and stiffness, under all circumstances, to safely carry the train; and the numerous trips that I have myself made over it with the locomotive and cars, practically verify these theoretical calculations.

But for the purpose of more tangible verification, I caused one of the longer girders to be loaded, in my presence, with a known weight of nearly double the amount that could be brought upon it by the train, and noted myself the results, by gauges arranged to show the deflection. The girder experimented upon is about forty-six feet long, and its lower boom is about eighteen feet above the surface of the ground. Two large iron cylinders (rendering tanks) laid on cross timbers, were suspended under the exact middle of the girder by means of a heavy chain passing over the upper boom. The tanks were then filled with water, making an aggregate weight of water, tanks, chain and timber, of 60,187 pounds, or about thirty net tons, equal to a distributed weight of sixty tons upon the girder—a load greatly in excess of any that could ever be put upon it by the train. The depression of the girder at its centre under this load was seven-sixteenths of an inch, and, on removing the load, the girder sprang back to its original position.

To test, practically, the power of the girder to resist lateral strains arising from pressure of wind and unbalanced loads, computations have been made, based upon the force of a hurricane blowing 110 miles an hour squarely against the side of the train, when the load is out of balance by passengers being at the same time all on the leeward side of the car. The side-pressure on a girder, arising from these extreme conditions, is computed to be equal to about $4\frac{42}{100}$ tons. By means of a cable, attached to the centre of a girder, and passing horizontally over a loose pulley in the top of a shear, and suspending vertically a platform loaded with pig-iron, I applied a force of $5\frac{29}{100}$ tons, to pull the girder sideways, being an excess of twenty per cent. over the computed extreme force of combined hurricane and unbalanced load. The side-deflection of the girder at its middle caused by this pressure of $5\frac{29}{100}$ tons was three-eighths of an inch. This pressure caused the posts supporting the girder under test to bend at their tops one-half of an inch. On removing the weight, the girder and posts sprang back to their original position.

As the iron posts are of good design and well-built, and securely fixed in place by foundations of timber and concrete, and have stood the pressure and strain of the train passing over them at frequent intervals for some months, I consider them satisfactory, and that no further test of their strength is necessary. The method of filling them with concrete, so arranged as to mainly take the weight, instead of leaving it to be supported by the iron shell, is especially commendable.

The wooden posts, now in use on the low part of the structure, answer very well for experimental purposes, but in a line intended for city traffic, I should advise that iron posts filled with concrete be adopted in all cases.

The structure of this experimental piece of railway, as now submitted to my examination, is, in my opinion, safe, and sufficiently strong, except in the plate-angle iron rails on the lower boom of the girder, which have proved too light, and are about to be replaced with heavier ones. It contains, however, objectionable curves and grades and angles, purposely placed there for extreme tests, to show what obstacles may be overcome if necessity compels them to be encountered, and to find out what changes may be desirable in the proportions of the machinery. In my opinion, these extreme features should be eliminated, and, wherever possible, kept out from any line intended for business purposes.

The motive-power and rolling-stock submitted to my examination, consisted of a locomotive weighing about thirty tons, a tender weighing about fourteen tons, and a passenger car weighing about seventeen tons, making up a train of about sixty-one tons, aggregate weight, when empty.

Excepting the distinctive running gear, or trucks, of this railway system, the general features of the motive-power and rolling-stock correspond to, or are supposed improvements upon, the locomotives and cars of ordinary steam railways.

A cylindrical shape has been adopted for all the equipment; for which shape peculiar advantages are claimed as to safety, convenience and economy, and particularly as to offering less resistant surface to the wind.

The car is more elegant and commodious internally than ordinary cars, and, being largely built of metal instead of wood, is

safer as regards fire, or as regards splinters, in case of accident. The turn-table arrangement of the trucks also seems stronger and safer than the trucks now in common use.

The leading features of the system centre in the trucks. They are constructed to straddle the girder, so that, if all the bearing wheels were knocked off, the fall of the truck would not be over two or three inches, or to the top boom of the girder, on which it would slide or rest.

The wheels that bear the weight instead of being placed in the ordinary upright position, are fixed at an angle of about 45° from the vertical plane. The bearing face of the wheels is grooved to fit down upon the angle-iron supporting rail, on the upper corners of the lower boom of the track girder, so as to bear both downward and inward on the rail. Each wheel has its own independent axle, securely fixed in the iron jaw of the truck, at right angles to the plane of the wheel. By this arrangement, the axle strains and the slipping of wheels on curves, so troublesome in axles of the ordinary construction, are wholly avoided; and it becomes possible to use sharper curves in the track than have ever before been practicable. Each truck has also two horizontal guide-wheels, bearing against the rails on the sides of the upper boom of the track girder, to prevent the truck from swaying.

As the sustaining rails of the track on the lower boom of the girder are but twenty-two and one-half inches gauge, and the wheels stand sloping outward from these rails, on an angle of about 45°, the first appearance of the rolling-stock to a casual observer, is one of extreme instability. But upon investigation and practical test, this appearance is found to be deceptive. Careful mathematical and mechanical analysis of the arrangement of the wheels and axles shows the plan to be theoretically correct; and that, as a matter of fact, this arrangement of trucks, upon properly constructed girders, is more stable and safer, than the trucks of ordinary rolling-stock upon the ordinary railroad tracks.

For the purpose of testing the safety of these trucks in the event of accident, I caused one wheel to be removed from a truck under the car, so that the car would be in the condition of losing a wheel by breakage while in motion. The train was then run over the track with one wheel gone. There was no perceptible tipping of the truck on account of the absence of this wheel, and

no apparent tendency to derailment. The absence of the wheel would not be noticeable to passengers in the car.

I also caused a section of the supporting rail and timber of one side of a lower boom to be cut away and removed, leaving an open gap of about six feet in the track. The car was then pushed over this gap, and, of course, became derailed; but it only dropped about two inches, and slid along on the upper boom as securely as if on its wheels. The centre of gravity being but little above the boom on which the car rested, the side wheels and track jaws held the car effectually in horizontal position, with very little strain. Apparently, a derailed car, on this system, could not tip over, which cannot be said of ordinary railroad cars on the ordinary railroad tracks.

The locomotive has some minor novelties of construction beside the truck arrangement above alluded to, not necessary here to describe; but its main features are the horizontal driving-wheels which pull the train by side pressure on the rails of the upper boom of the girder, and the hydraulic attachment by which the pressure of adhesion of these driving-wheels upon the rails is created, maintained and regulated, at will, by the engine-driver.

This motor has accomplished some remarkable feats. It draws itself and the attached train, with apparent ease, and great speed, around sharper curves and up heavier grades, than the ordinary locomotive can pass. But, being the first of the kind ever built, of full size, and having been from the outset put at work on a track purposely planned to bring out in this experimental stage any existing weakness of design (through trial on unusual grades and curves and angles, requiring machinery of great perfection and power to overcome these extraordinary obstacles), it has, as might be expected, proved weak in some of its minor proportions, and there has been more or less breakage in the strained parts. All the defects thus far developed seem, however, to be susceptible of easy remedy, and no doubt, in future construction, the proportions of the parts will be greatly improved.

With so radical a departure from the ordinary mode of applying locomotive-power, it is only to be expected that perfect proportions will develop slowly, and out of the results of extended use, or practical experiments. This is but the usual rule, applying to all inventions

The result of my investigations may be summed up as follows:

The experimental section of the Meigs elevated railway now in use at East Cambridge is, in my opinion, abundantly strong for its intended use as an elevated railway track, and is safe for the passage of its equipment.

The rolling-stock and motive-power used thereon are also strong and safe for their intended use, no breakage having occurred, or being likely to occur, that could imperil personal safety, either in or out of the cars.

A line of railway, properly constructed on this principle, for passenger or freight traffic, and equipped with such rolling-stock and motive-power, on this principle, as the Meigs Company is now prepared to perfect and build, would, in my opinion, be, at least, as strong and safe for any kind of traffic as the ordinary surface or elevated steam railways now in common use.

In view, however, of the imperative necessity for the best class of design and construction in everything appertaining to an elevated railway, I think it would be wise for the state of Massachusetts, through its board of railroad commissioners, or otherwise, to regulate the strength and design of all materials used in construction, and the weight and design of equipment to be run, etc., as is done by New York, through its "rapid-transit commission," for elevated railroads in that state.

I attach to this report some sketches, kindly furnished by Capt. Meigs, showing a perspective and a sectional view of his track and equipment, and the methods used by me for applying the weight and pressure tests to the girders and posts.

Respectfully, your obedient servant,

George Stark, *Civil Engineer.*

Boston, December 23, 1886.

ANNUAL REVIEW OF INDUSTRIAL PROGRESS.

[*From the Report of the Secretary, read at the Annual Meeting, January 19, 1887.*]

THE YEAR 1886 was characterized by the continuance of the favorable conditions which were well-defined towards the close of the year which immediately preceded it, and, in spite of the serious check to commercial and industrial activity, caused by the prolonged and widespread labor troubles, it was a notably prosperous year, and witnessed a substantial and very general revival of our industries.

The industrial revival was reflected in the most satisfactory manner in the iron trade, in respect to which the year 1886 was the most prosperous ever known in the history of these industries in the United States. Though it is too early to give the figures of production with strict accuracy, the estimates which have just been published by Mr. Swank, the Manager of the American Iron and Steel Association, and from which I abstract the more important data, will afford a sufficiently close approximation to answer my purpose in this review.

In his annual summary of the iron trade, which appears under the significant caption, "A Prosperous Year," Mr. Swank remarks, that the improvement which commenced in 1885 was continued, with but slight interruption, throughout the year, which was one of great activity. He gives us the following facts and figures: Our production, in 1886, of pig iron, Bessemer steel and steel-rails, open-hearth steel, structural iron and steel, and some other products, has been much larger than in 1885, and our production of pig iron, Bessemer steel, Bessemer steel rails, and open-hearth steel has been much the largest in our history. He estimates the production, in gross tons, of these four leading products in 1886, compared with the production in 1885, to have been as follows:

Products.	1885. Gross Tons.	1886. Gross Tons.
Pig Iron,	4,044,526	5,600,000
Bessemer steel ingots,	1,519,430	2,000,000
Bessemer steel rails,	959,471	1,500,000
Open-hearth steel,	133,375	200,000

He adds, "the figures for 1886 have been estimated with care, and we believe will be fully verified by the official returns, which we are now collecting from the manufacturers. They are marvellous in their mere magnitude, but more marvellous still in showing our progress as iron and steel producers in one year. Our production of iron ore in 1886 was about 10,000,000 tons, and we imported about 1,000,000 tons. During 1886, this country built over 7,000 miles of new railroad, against 3,131 miles reported by Mr. Poor for 1885. This great increase in railroad building in 1886 contributed largely to the improvement in our iron and steel industries."

It is worthy of special note, in this relation, that during the past year

the United States outstripped Great Britain as a producer of at least one important product—namely, Bessemer steel, and that, assuming the same ratio of increase to be maintained, at the close of the present year, we will have also taken the lead as producers of pig iron. These comparisons, apart from their interest, are instructive, since they exhibit perhaps more strikingly than any other form of illustration, the rapid growth of this country, both in respect to its productive capacity and its consumption.

The domestic production of coal has kept pace with the increased production of iron and steel, and the increased activity of our domestic manufactures, and the production for the year 1886, though as yet it is too early to obtain correct figures, will undoubtedly be found to be larger than that of any previous year in our history.

In Constructive Engineering, I have no remarkable advances to record. The more interesting items that seem noteworthy are the following:

The subject of enlarging the facilities of the Suez canal, to which reference was made in my report for last year, may be considered as definitely settled. The commission of engineers, which was appointed, in 1884, to decide upon the most feasible measures to be undertaken to enable the ship canal to meet fully the exigencies of a traffic exceeding 10,000,000 tons per annum, after a full consideration of the three methods proposed for increasing its carrying capacity —namely: (1), widening the existing canal; (2), constructing a second canal; and (3), doubling the capacity of the canal by a combination of the first two methods—has decided unanimously in favor of the enlargement of the existing canal from the Mediterranean to the Red Sea. The principal reasons assigned for this decision, were, that it would permit vessels to increase their speed through the canal from five and one-third to eight knots per hour, thus shortening the time of passage to twelve hours; that there would be only two banks to maintain instead of four; that the danger of collision between passing vessels would be lessened; and that it would enable each successive portion of enlargement to be at once utilized as an addition to the passing places for vessels. The estimated cost of this enlargement is placed at about $40,000,000.

Statements and opinions concerning the actual condition and prospects of the Panama canal are as conflicting as ever. The projectors of the enterprise appear to have succeeded in obtaining a considerable addition to their funds, independent of the Government aid which was asked for, and during the past year the work of excavation has been considerably advanced. They speak as positively as ever of the completion of the canal, and announce that it will certainly be opened for traffic in the year 1889. On the other hand, it does not appear that those portions of the work, which have excited the gravest apprehensions respecting their feasibility, have thus far been touched; charges of gross mismanagement, and extravagant expenditure of money, have been freely made; and prediction of the total collapse of the enterprise has been ventured by the most eminent financial authority in France. Whatever view one may take of the ultimate fate of the enterprise at the hands of

its projectors and present managers, it is now admitted, that the canal will cost a vastly greater sum than they imagined it would, and that they greatly underestimated the difficulties of their undertaking.

Mr. Geo. W. Plympton, discussing the much-debated project of flooding the Sahara, disposes of the exaggerated notions entertained of the extent of the area which would thus be flooded, by showing that the united areas of the several "chottes" over which the sea would flow, is about 3,100 square miles, or less than half the area of Lake Ontario.

The Eads's ship-railway project is still discussed, and though its advocates were not successful last year in inducing Congress to act favorably on their proposition that the United States should join with Mexico in guaranteeing to make good a certain amount of income for a series of years, it is not improbable that a further effort in this direction may have better success, or, that the work may be assumed by private enterprise.

The work upon the new Croton aqueduct, which was referred to in my last yearly summary, has been considerably advanced, but will still require several years for its completion.

It may be of interest to note, in this place, that the subject of improving the condition of the water supplies has attracted more attention during the past year from the authorities of American cities than ever before. The city of Chicago is engaged in perfecting plans for an improved and more abundant supply, and in Philadelphia, the results of a very thorough survey, undertaken to determine the best source for its future supply, have just been published.

IN THE FIELD OF ELECTRICITY, while the year of 1886 was not distinguished by any notable discovery, substantial advances were made in many of its practical applications. I shall take note of those only, which appear to be the most important.

In *telegraphy*, the ingenious system of Mr. Lucius J. Phelps, of transmitting messages to and from railway trains in motion, by utilizing the principle of induction, which received the distinction of an award of the Scott Legacy Premium and Medal, on the recommendation of this INSTITUTE, and which was noticed in my summary of the previous year, has been improved in its practical details. It has lately been placed in operation on the Lehigh Valley Railroad, and, I am informed, is shortly to be introduced on the main line of the New York, New Haven and Hartford Railroad. A system, having the same object in view (that is, transmitting messages to and from moving railway trains), but employing static induction, was proposed during the past year by Mr. Edison, and was widely talked-of in the technical journals. From all that I can learn of this system, certain practical difficulties have been encountered in its operation, which have not yet been overcome, but, for an inventor of such fertility of resources as Mr. Edison, these difficulties are not likely to prove insurmountable.

In fac-simile *telegraphy*, an ingenious system of transmitting diagrams,

charts, sketches, etc., has been proposed by two English officers, Lieutenant-Colonel Melville and Lieutenant Glen, which promises to prove a useful acquisition for military purposes. It consists, substantially, in dividing a blank sheet into a number of blocks or squares, each of which shall be designated by a number or letter, on a pre-arranged scheme. By telegraphing a series of these numbers or letters, a series of dots will be obtained, which, when joined so as to make continuous lines, will form the desired outline or tracing.

In *multiplex telegraphy* there is nothing of importance to record. In *submarine telegraphy*, the adoption by the Mackey-Bennett lines of the Muirhead system of duplicating may be noted as a substantial advance. The *Electrical World* notes, as an advance in *land telegraphy*, the duplexing of lines by the use of the condenser, which has made it possible to employ the telephone as a receiver supplementary to the ordinary telegraph relay. This plan also is the invention of Mr. Edison, and is called the "phonoplex." It renders it practicable to work duplex to any intermediate station on a line, which was not possible by the old duplex system. The system has found its practical application in railroad telegraphy, where many stations are, as a rule, included in the same line.

In *telephony*, some progress has been made in the establishment of long-distance lines. A number of lines were in practical operation between New York and Boston during the past year, and the results were so satisfactory that a number of lines have been constructed between New York and Philadelphia. The system employed is said to be that of Mr. Gilliland, in which a continuous metallic circuit is used. It is probable that the present year may witness the considerable extension of long-distance telephony.

In connection with this branch of the subject, the suggestive experiments of Messrs. Bell and Taintor, in reproducing spoken words by means of "sensitive jets," are worthy of note; as, likewise, are the experiments of Professor Dolbear in establishing telegraphic communication without the use of a metallic conductor, and which gives promise of success.

The past year witnessed the continued extension of *electric lighting*, both for public and domestic uses. Improvements in great number have been announced, but none appear to be of a radical character. Considerable discussion has been called forth on account of the alleged advantages of the Gaulard & Gibbs system of employing alternating high-tension currents, and converting these, by means of an induction-apparatus, into low-tension currents suitable for incandescent-lighting. By this system of distribution, a great saving of copper for conductors is claimed to be effected, and the cost of service greatly diminished. The practical value of this system still remains to be demonstrated. It is stated that preparations are being made by the Westinghouse Company to introduce it upon an extensive scale, in connection with a scheme of introducing fuel-gas, in which the existing gas-light companies will be invited to participate.

The subject of *electric transmission* received its full share of attention. The use of electric motors has considerably increased, and electric-lighting companies, finding it profitable to rent out their current during the day-time

when it is not required for lighting, are systematically encouraging its use. The *Electrical World* reports that the number of electric motors of all kinds in use in the United States exceeds 5,000, and that this number is increasing very rapidly. The same authority speaks hopefully of the *electric-railway*, of which it predicts that it "will be nothing less than revolutionary in its effect upon inter-urban transit."

In the construction of *primary* and *storage batteries*, the record of the past year reveals no improvements of a radical nature

The *electric-smelting* process of the Cowles Brothers, which this INSTITUTE has crowned with its highest honors, has continued to justify the favorable opinions which all thoughtful observers have entertained respecting its capabilities. During the past year an electric-smelting plant, on a greatly-enlarged scale, has been erected and put in operation at Lockport, N. Y., and is at present running at its full capacity. The only commercial products turned out thus far are the aluminium bronzes, for which, at the reduced cost at which it has been found possible to manufacture them in the electric furnace, there appears to be a large and constantly growing demand.

An invention of much interest in this field is the process of *electric welding*, which was brought out last year by Prof. Elihu Thomson, an honored member of this INSTITUTE. By this process it is said to be possible, not only to effect the welding of pieces of metal which cannot otherwise be welded, but also to weld pieces of different metals. The invention, it is affirmed, is capable of general application.

Finally, I will notice, in taking leave of this theme, that the subject of *underground wires* in cities has received more general attention and discussion during the past year than ever before, and, that in a number of places, notably in New York, Brooklyn, Philadelphia, Boston and Chicago, substantial progress towards the practical solution of this troublesome problem was realized.

IN CHEMICAL TECHNOLOGY, the procedure proposed by Mr. H. Y. Castner for the production of the metals of the alkalies, by which, it is claimed, the cost of these important products will be considerably reduced, appears to be worthy of notice. Mr. Castner's improvements relate principally to the employment of a metallic carbide (in the form of a carbide of iron) to effect the reduction, which he claims to be able to accomplish at comparatively moderate temperatures, with the charge in a state of fusion, and claims, further, to obtain practically the entire yield of metal contained in the charge. By the process used down to this time, the temperatures required are very high; the wrought-iron retorts employed are speedily burnt out; only small charges at a time can be operated with, and the yield is not much above thirty-three per cent. Mr. Castner's claims are now being subjected to the test of a practical examination, and if they are substantiated, the invention will prove valuable, as the cheap production of sodium will affect many branches of the chemical and metallurgical arts.

REVIEWING THE PROGRESS of the great industries of mining and metallurgy, the *Engineering and Mining Journal* gives the following interesting summary, which indicates for these industries a remarkable degree of progress, technical and commercial:

"Never before in this country was the number of paying mines so great, or its proportion to the whole number worked so large. And never before were the improvements in metallurgy so interesting or their results of greater practical importance. The cost of production of every metal has been reduced.

"In mining, the wonderful skill evolved from intelligent experience with machine-drills, and the introduction of cheap high explosives, have brought our ordinary every-day work to a point in speed and economy that a few years ago would have been considered as improbable as the telephone. Coal-cutting machinery and mechanical underground haulage are effecting a notable economy in the cost of producing that most important of all mineral products—coal.

"The twenty-ton copper-furnace has given place to the simple little water-jacketed shaft that smelts from 100 to 150 tons a day at an expenditure of about as many cents as it formerly cost dollars; the successful application of the Bessemer method to the treatment of copper ores; a vast increase in the capacity and economy of lead furnaces; the reduction in the cost of the treatment of zinc ores, which has brought this metal down to, and even below, the price of lead; improvements in the production of sulphuric acid that have made half a cent a pound for commercial acid a profitable price, even where the pyrites used have come from distant Spain; improvements in the crushing, concentration, roasting, amalgamation and chlorination of gold and silver ores; in the bromination of gold ores; in the electrical separation of metals; in furnaces and machinery used in the production and manufacture of iron and steel, which have made possible the wonderful records of our iron and steel works; excellence in design and construction of bridges; of locomotives, and machinery of all kinds, which have demonstrated to the outer world their superior economy and efficiency, compared with old-world types; the cheaper production of electricity and its general application for power, light and heat; progress in the practical utilization of waste products. These and many more are subjects in which our American engineers have made, and are making, records that challenge the attention and admiration of the world."

IN MAY, 1885, Mr. Nordenfelt exhibited at the meeting of the British Iron and Steel Institute some remarkable specimens of castings made by the direct melting of wrought iron, which at once attracted attention, Much curiosity was manifested to learn by what process such results, heretofore only obtainable by the method of forging, had been obtained. Since then the details of the process have been given to the public, and the past year has witnessed the practical introduction of the "*mitis*" process of producing wrought-iron and steel castings in Europe and in this country. The process depends upon the addition, to the raw material employed, of an exceedingly small percentage of another metal, which has the effect of

causing an immediate and considerable lowering of the melting-point of the wrought iron used in the operation. This remarkable effect is produced by the addition, to the charge of wrought iron heated just to the point of fusion, of from 0·05 to 0·1 of one per cent. of aluminium, in the form of an alloy of iron and aluminium. By this addition, an immediate lowering of the melting point of the charge is produced, and the charge at once becomes thinly fluid; and, being superheated to the extent of perhaps 500° F., it may readily be handled and poured into castings before chilling sets in. For the practical working of the process, a number of special improvements in the form of the heating furnaces employed, in the mode of casting, etc., have been devised, and the process appears to be practically successful. It has lately been introduced into the United States. In this relation, the following brief quotation from the comments on this process, which I made at a recent stated meeting of this INSTITUTE, and which were published in the JOURNAL several months ago, may not be out of place.

"The simplicity of this process, the certainty with which it can be operated, the uniformity of the product, and its admirable qualities in respect to strength and ductility, indicate an extended field of usefulness for it. The most difficult forms have been successfully produced in mitis castings, such as pulleys, smoke-consumers, wheels, knees, bends of piping, etc., having the tensile-strength of mild steel forgings, at but slightly greater expense than for castings of ordinary shape; and it is claimed, with good reason, that there is scarcely any form of forging which it would not be more advantageous to cast by this method. The mitis castings threaten to seriously incommode the manufacturers of malleable castings, for which they not only offer a perfect substitute, but one which, in respect to strength and ductility, is distinctly superior; while for many purposes, mitis castings can be employed for which malleable castings could not be made. The mitis process has also been applied to the production of steel castings, and with very promising results."

It is of interest to record the fact that the element *fluorine*, which has hitherto obstinately resisted all efforts to isolate it, has at last been obtained in its elemental state, by a French chemist, M. Moissan, who, with great difficulty and with the aid of most ingeniously-contrived apparatus, succeeded in separating it from its combination with hydrogen by the electrolytic method.

Fahlberg's *saccharine*, though not a recent discovery, attracted some attention during the past year. The discoverer has been busily engaged in improving its manufacture with the view of cheapening the cost of production, which, by the latest published statements, has been brought to about $12.50 per pound. Though this appears very high, it is not prohibitive of its use as an addition to glucose, since its sweetening power is so great. The experiments that have been made with it seem to indicate that it is quite harmless, and that in addition to its extraordinary sweetness (which is estimated to be 230 times greater than that of cane sugar) it possesses decided antiseptic powers. It may soon find practical application as an addition to glucose for the various uses to which this substance is put.

In last year's summary, I noted, at some length, the remarkable revolu-

tion in industrial and domestic economy, which the general introduction of *gaseous fuel* had brought about in the cities and towns situated within the natural gas belt. During the past year, the growth of the gas producing industry, and the substitution of the new fuel for the old, have continued at so rapid a rate, that the most enthusiastic advocates of the change are amazed at its extent.

Passing by the use of gaseous fuel for domestic purposes, as of secondary importance, there can be no doubt of the fact that the adoption of natural gas for fuel by the iron, steel and glass manufacturers of Pittsburgh and its neighborhood has given so great an advantage to these industries in that favored region, that competing manufacturers elsewhere, in many instances, have found themselves compelled to remove their establishments to some point within the gas region, and many others are considering the expediency of following this example at the first opportunity.

While the immediate results of the circumstances here referred to, must be to give a great impetus to manufactures of all kinds in the cities and towns lying within this favored region, it is scarcely conceivable that they will be permitted to enjoy exclusive advantages indefinitely; for, with the knowl- that there are means available for the artificial production of fuel gas at a cost sufficiently low to compare favorably with the prices at which natural gas can be supplied, the manufacturers in every industrial centre throughout the country, sooner or later, will be compelled, in self-defence to adopt this expedient.

Far-sighted men are already discussing the feasibility of converting the existing coal-gas works in our cities and towns into fuel-gas works, thus utilizing the existing mains and distributing pipes, and, by the simultaneous introduction of the incandescent system of electric lighting, effect at once a two-fold revolution.

THE PAST YEAR will be memorable in the annals of the country for the destruction of a large portion of the city of Charleston, S. C., on the 31st of August, by an earthquake, the effects of which were felt over an area of 900,000 square miles. The immediate vicinity of Charleston appears to have been the centre from which the disturbances emanated, and the destruction of property in that city was enormous. The only offset to this great calamity, is the fact that, destructive as it was to property, comparatively few lives were destroyed.

REPORTS OF THE COMMITTEE ON SCIENCE AND THE ARTS.

[No. 1348.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 31, 1886.

The Sub-Committee of the Committee on Science and the Arts, to which was referred the products of the Celluloid Manufacturing Company, of Newark, N. J., presents the following report:

The very fine display, which the Celluloid Manufacturing Company, of Newark, N. J., made at the late "Novelties" Exhibition of the FRANKLIN INSTITUTE, led the judges of the group under which they were classified to recommend the award to them of a silver medal, and to call the attention of the Committee on Science and the Arts to the very meritorious character of their exhibit.

Sub-Committee No. 1348, to which the matter was referred, has examined the claims, as presented at that time, and has considered additional statements made by the company as to their recent efforts to find new avenues of useful employment for this material, and one of the committee has visited the factory of the company, at Newark, and has seen their manufacturing processes in detail.

The committee believes that in celluloid has been found a very valuable substitute for ivory, a natural product growing scarcer every succeeding year. Many articles, formerly made from ivory, like piano-keys, billiard-balls, handles for cutlery, etc., are now made, not only cheaper, but better, from celluloid, the perfect uniformity in appearance of which, and its density and freedom from tendency to crack make it in every way superior to ivory. Similarly, for amber and vulcanite, celluloid makes a very desirable substitute. Especially for the latter, has it been advantageously substituted in the manufacture of plates for artificial teeth, in which the amount of pigment, necessary to give them the color of the natural gum, is only a small fraction of that necessary for vulcanite. Moreover, celluloid is entirely free from sulphur, a necessary ingredient of vulcanite.

The company showed, moreover, in their exhibit, that celluloid was admirably adapted for a great variety of uses, and that in each case it had positive advantages over the material it replaced.

One of the most important applications of celluloid, which the company have been busily pushing since the time of the exhibition, is its use in the manufacture of stereotype plates for print-

ing. Here it replaces, with numerous advantages, too, the heavy and expensive metal castings. These celluloid stereotype plates are light, tough and elastic, and can readily be sent through the mails. They take ink freely, give excellent impressions, and can be easily cleaned and dried. With the aid of these celluloid stereotype plates, the news associations of the large cities are able to supply the newspapers of interior places with matter ready for printing at very low prices.

The Sub-Committee, recognizing the part the Celluloid Manufacturing Company has had in developing the possibilities of this new material, by their expenditure of labor and capital in pushing the invention of the Hyatt Brothers, and their continual work in experimenting with reference to new applications of celluloid, would recommend the award to the company of the ELLIOT CRESSON GOLD MEDAL, *for the introduction of a new raw material of great possible value, and for its successful utilization in many important industries.*

W. C. HEAD, SAM'L P. SADTLER, *Chm.*,
H. C. SELLERS, WM. H. WAHL.

Adopted December 1, 1886.

H. R. HEYL, *Chm.*, *Committee on Science and the Arts.*

[No. 1358.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, August 30, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination the

AIR-BRUSH

of the Air-Brush Manufacturing Company of Rockford, Ill., respectfully

Report: That after an examination of the instrument and its uses, they regard it as deserving of the warmest commendation. The application of the principle of the air-brush to a tool for distributing liquid pigments on to paper or other surfaces in the production of pictures, is a great novelty in the arts, and as important in its economy of time as it is novel. In the hands of an accomplished draughtsman, it is an acquisition of rare value.

Of course, this instrument cannot make up for any deficiency of

artistic skill in the operator, for, as much proficiency in drawing practice is necessary with this as with any other of the pencils or brushes heretofore used. What is chiefly claimed for it by its inventor is, that it facilitates his work by shortening greatly the time consumed in the execution, and that it is more durable than crayon or pastel when used in imitation of those styles. Artistic displays of freedom of touch can readily be added over the finished work of the air-brush by those who prefer to do so, and still the work will appear homogeneous in method of execution when the same pigments are used in both cases.

One of its merits, is that tints laid on by means of the air-brush possess the advantage of appearing equally well whether the light falls on them from one side or the other. This is not the case with tints made with the crayon, as is well known, for the reason that the toothed surface of the paper gets more completely covered on the side towards the light than it does on the shaded side, consequently, a drawing that appears smoothly finished in the light in which it was drawn, is apt to look rough and coarse when viewed with the light falling on it from the opposite direction. The reason of the difference is obvious—the air-brush throws the color directly down into the pores of the paper, covering equally both sides of the projecting tooth of the surface, so that naturally the work looks well in whatever light it is shown.

The manner in which the air-brush delivers the color to the paper may be described in few words, thus: the artist supplies liquid color from a brush to a spoon-like reservoir. Through this liquid a fine needle darts rapidly back and forth, its wetted point being carried forward beyond the edge of the spoon. A strong current of air blown against this needle's point carries off the small amount of color adhering to it in finely divided particles, thin and fine at the point of departure, but widening out as its distance increases. Hence, if the instrument is held near the paper, it will make fine lines, when moved as in writing, but removed to a distance, it will make broad, soft tints with gentle blendings. The greater or less length of stroke of the needle, as well as the current of compressed air playing on it, is all the time completely under the control of the artist by action of his thumb while working, the supply of air to the chamber being pumped in by action of his foot.

We have only to add that this remarkable invention is an

important aid to the artist, and we believe it deserves the highest award that the FRANKLIN INSTITUTE has in its power to bestow.

JOHN SARTAIN, *Chm.*,
JOHN CARBUTT,

November 3, 1886.

Amended to incorporate the award of the ELLIOT CRESSON MEDAL, and as so amended adopted. H. R. HEYL, *Chairmen.*

[No. 1306.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 28, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

THADDEUS S. C. LOWE'S INVENTIONS AND IMPROVEMENTS IN THE MANUFACTURE OF FUEL WATER-GAS AND INCANDESCENT BURNERS FOR SAME,

Report: That there was referred to them—

(1.) His water-gas processes in general;

(2.) His manufacture and utilization of fuel-gas, and

(3.) His forms of incandescent burners for using fuel-gas as a source of illumination.

They did not formally organize for service until some considerable time after the date of appointment. A number of the members of the committee went, by invitation, to Norristown, in May, 1885, to see the works of Prof. Lowe and to inspect his incandescent burners as arranged at his office. We were asked, however, to wait until a more complete exhibit of them could be made at the "Novelties" Exhibition of the FRANKLIN INSTITUTE in the fall. Then, as Prof. Lowe's different exhibits were to be reported upon by several of the groups of judges appointed in connection with this Exhibition, it was thought best not to present anything until their reports had been made.

In February, of this year, Prof. Lowe asked to be allowed to appear before the Sub-Committee and read a paper, in which he presented a statement as to his connection with the water-gas inventions, and dwelt upon its value present and prospective. After this, the committee met at the Hall of the INSTITUTE for consideration of the work allotted to it, and determined upon their general

line of action. But, in the meantime, a committee of the judges of the late "Novelties" Exhibition were preparing a historical review of the whole water-gas subject, which they presented May 1, 1886.

Thus it has happened, that in addition to the abundant literature before available, three reports have been made on this very subject in connection with the late Exhibition of the INSTITUTE, and which are appended to this report for descriptive and other information.

The committee have therefore considered that sufficient reliable data already exist from which to allow them to express an opinion, and have not undertaken any new experimental studies of the processes or inventions

They would therefore state:

(1.) That they agree with the Special Committee of Judges in considering that the combination of the three principles (*i. e.:* of internal combustion, of admitting air and steam to the generator alternately, and of the use of a regenerator "in practicable form for the special purpose of producing a gaseous product suitable either for fuel or illumination), does not appear to have been made or suggested prior to the date of the first publication of what has since come to be known as the Lowe process," and "that this combination of elements constitutes a material improvement in the practice of the art of water-gas manufacture."

(2.) Admitting what no longer admits of dispute, viz.: that gaseous fuel will in the future displace solid fuel wherever the two really come into competition, the committee find that Prof. Lowe's inventions are of very great value in this connection. He produced, at the Exhibition, a fuel-gas containing by volume 3·6 per cent. of CO_2, 42·1 per cent. of CO, 44·5 per cent. of H, and 9·8 per cent. of N, and claims that such gas can be manufactured on a large scale at ten cents per 1,000 cubic feet. This claim the committee have had no opportunity of verifying. Moreover; his various forms of ovens, heaters, ranges, stoves, open-grates, etc., seem to be admirably adapted to serve their intended purposes.

(3.) In testing Prof. Lowe's incandescent burners, made of platinum spirals, for use with non-luminous fuel-gas, the Committee of Judges, at the late "Novelties Exhibition," found an efficiency of 1·40 candles per cubic foot of gas consumed. Prof. Lowe claims that the material does not wear out, and that if bent or broken by accident, they can be replaced at a trifling cost, as the

platinum is always capable of being worked over without loss. They certainly gave a pleasing and agreeable light, as exhibited at the late Exhibition.

The Sub-Committee would, therefore, recommend that the ELLIOT CRESSON MEDAL be awarded Prof. Thad. S. C. Lowe, for his great services to the cause of gas-lighting in connection with his water-gas process, and for his improvements in the manufacture of fuel-gas, and of apparatus for utilizing the same for a variety of purposes.

SAMUEL P. SADTLER, *Chm.*, WM. H. WAHL,
GEORGE A. KOENIG, OTTO C. WOLF,
LEWIS M. HAUPT, HENRY PEMBERTON, JR.,
PEDRO G. SALOM,
Sub-Committee.

Adopted July 7, 1886.

H. R. HEYL, *Chm. Committee on Science and the Arts.*

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 19, 1887.*]

HALL OF THE INSTITUTE, January 19, 1887.

COL. CHAS. H. BANES, President, in the Chair.

Present, 105 members and eight visitors.

Number of new members added since last meeting, eleven.

Reports were presented from the Board of Managers and various Committees, as follows:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1886.

The Board of Managers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the INSTITUTE for the year 1886.

MEMBERS.

Membership at the close of 1886,	2,257	
Number of new Members elected, who have paid their dues,	87	
		2,344
Lost by death or resignation,	63	
Dropped for non-payment of dues,	59	
		122
Total membership at close of 1886,		2,222

FINANCIAL STATEMENT.

Receipts.

Balance on hand January 1, 1886, ...		$810 78
Exhibition of 1884, ...	$18 26	
Exhibition of 1885, ...	393 96	
Exhibition of 1885. Net amount from sale of property after deducting expense of clearing ground and fencing the lot, ...	3,184 32	
Received from Guarantee Fund on account of loss incurred by Exhibition of 1885, ...	5,130 49	
Cash from sale of securities, ...	10,000 00	
Cash from other sources, ...	12,480 11	
		31,207 14
		$32,017 92

Payments.

Committee on Publication, ...	4,117 33	
Publication of Reports, ...	698 95	
Exhibition of 1885, ...	2,628 93	
Paid on account of temporary loan, ...	10,000 00	
Interest on temporary loan, ...	514 76	
Endowment of Memorial Library (invested), . . .	902 70	
Other expenditures, ...	12,054 30	
		30,916 97
Balance on hand December 31, 1886, ...		$1,100 95
There still remains to be collected of the Guarantee Fund, ...	1,717 78	
Remaining unpaid on temporary loan, ...	*5,000 00	

LIBRARY.

During the year 1886, there were added to the Library 1,325 bound volumes, 512 unbound volumes, ninety-six maps and charts, and 1,817 pamphlets, making a total of 3,754 additional titles. Although these figures fall below those of 1884, when the Memorial Library was added, and 1885, in which 1,300 volumes were added by gift of the heirs of the late Prof. Robt. E. Rogers, the exhibit is a highly creditable one. The whole number of books bound and unbound, in the Library, December 31, 1886, was 27,998. This is exclusive of pamphlets in the main and pamphlet libraries, the number of which is between 8,000 and 9,000.

The catalogue of the pamphlets was completed during the year, and is now accessible for reference. The lack of accommodation, for the proper display and accessibility of the volumes in the Library, so frequently referred to in

* The INSTITUTE has invested funds to the amount of about $30,000, the income of which is available for the general purposes of the INSTITUTE. It should be said, however, that the income from this and from all other sources, for a number of years, has not been sufficient to meet the expenses.

previous reports, was felt more severely, although an attempt to remedy it has been made by removing a considerable number of volumes to the third story.

Additional details appear in the report of the Library Committee.

THE JOURNAL.

The JOURNAL was more than self-supporting during the past year, and has advanced both in the value of its contents and the amount of its business The index is substantially completed, and arrangements for its publication during the present year are now being made, which, it is expected, will be successful.

The Committee on Publication has succeeded in obtaining the voluntary services of a number of collaborators, with whose assistance, it is reasonable to expect, that the usefulness of the JOURNAL will be notably increased. The Board of Managers takes this opportunity to commend the JOURNAL to the members of the INSTITUTE, among whom its circulation is not as large as it should be. It is worthy of a generous support.

LECTURES.

The following Lectures were approved and delivered during the past year. By Dr. Henry F. Formad, *one*, on "Germs, their Influence on Health;" Mr. M. N. Forney, *one*, "The Evolution of the American Locomotive;" Prof. S. T. Sadtler, *one*, on Coal-tar Distillation;" Col. Wm. Ludlow, *one* on "Water-Supplies of Cities;" Col. Geo. E. Waring, *one*, on "Sanitary Care of Cities;" Mr. John Hartman, *one*, on "Blast Furnace Construction;" Mr. C. J. Kintner, *one*, on "The United States Patent Office Historical Electrical Apparatus;" Mr. Oberlin Smith, *one*, on the "Flow of Sheet-Metal in the Drawing Process;" Mr. Jas. Christie, *one*, on "Elementary Problems of Bridge Construction;" Mr. T. C. Search, *one*, on the "Technology of Worsted Manufacture;" Prof. M. B. Snyder, *one*, on "The Relations of Pure Research to the Electrical Exhibition;" Mr. Rudolph Hering, *one*, on "Sanitary Plumbing;" Mr. C. J. Hexamer, *three*, on "Petroleum and its Products;" Mr. Carl Hering, *two*, on "Dynamo-Electric Machinery;" Captain O. E. Michaelis, *one*, on "Electro-Ballistics;" Prof. De Volson Wood, on "The Education of the Mechanical Engineer;" Prof. Persifor Frazer, *four*, on "Elementary Chemistry;" Mr. E. A. Gieseler, *one*, on "The Illumination of Maritime Coasts;" Mr. J. Luther Ringwalt, *two*, on "The Development of Transportation Facilities in the United States;" Mr. S. Lynwood Garrison, *one*, on "The Microscopic Structure of Iron and Steel;" Prof. N. A. Randolph, *two*, on "Life and Death;" "Thought and Sleep;" Prof. Cleveland Abbe, *one*, on "Popular Errors in Meteorology;" Mr. Chas. A. Ashburner, *one*, on "Natural Gas;" and Prof. Albert R. Leeds, *one*, on "The Purification of Water-Supplies."

Thirty-two lectures are included in the foregoing list and many of them were of a high order of excellence and by gentlemen of eminence, of whom a number were non-residents.

The attendance, however, save in exceptional instances, was not notably greater than in previous years.

This indifference on the part of the members is somewhat discouraging to the Committee on Instruction.

The same plan respecting the issue of free tickets to members for distribution, that has been in operation for several years, was adhered to, and it appears to give general satisfaction.

DRAWING SCHOOL.

The Board refers with satisfaction to the continued efficient management of the Drawing School. The number of pupils in attendance was well up to the average of former years.

The attendance at Spring Term, 1886, was,	175	
The attendance at Fall Term, 1886, was,	197	
Whole number for the year,		372
An increase over the previous year, of,		39

COMMITTEE ON SCIENCE AND THE ARTS.

This Committee has been unusually active during the year 1886, owing to the large number of cases referred to it, by the judges of the "Novelties" Exhibition.

Reports were made upon forty-one cases; in nine of which the award of the Elliot Cresson Medal was recommended, and in ten, the award of the John Scott Legacy Premium and Medal. Three protests were entered against these recommendations, of which one was sustained, one was dismissed as immaterial, after due consideration, and one is still under consideration.

Six recommendations for the award of the Elliot Cresson Medal were reported to the INSTITUTE and were approved, after due advertisement in the JOURNAL. Six recommendations for the award of the John Scott Legacy Premium and Medal were similarly reported, all of which were approved, respectively, by the INSTITUTE, and by the Board of City Trusts. In one case, the Committee awarded a Certificate of Merit.

The amended By-Laws involve certain changes in the constitution of this Committee, which, it is anticipated, will increase its usefulness. Commencing with the year 1887, the Committee will consist of forty-five members, elected by the INSTITUTE. During the fifty-two years of its existence as a volunteer body, it has acted upon 1,368 subjects. While it would be exaggeration to say that it has not occasionally committed errors of judgment, its work, taken as a whole, has been highly creditable and useful.

SECTIONS.

The Chemical and Electrical Sections of the INSTITUTE have held regular meetings during the past year, and the attendance indicated a lively interest in their work. Several papers of importance were presented and discussed at the meetings and have been published in the JOURNAL, and a number of subjects have been investigated and reported upon at the solicitation of the Committee on Science and the Arts. Both sections exhibit a substantial increase of membership. The details of their work will appear in their Annual Reports, to which the Board refers.

THE EXHIBITION OF 1885 AND THE GUARANTEE FUND.

After the close of the last exhibition, it was deemed inadvisable to hold another upon the location in West Philadelphia.

The Committee was authorized to sell the building, fixtures and material, and after paying the expense of clearing the ground and fencing the lot, to apply whatever sum remained toward any financial deficiency. After this had been done, a careful statement was prepared and reported to the Board, manifesting a loss, by the Exhibition of 1885, of about $7,000. To meet this deficit, it became absolutely necessary to call upon the subscribers to the Guarantee Fund for their proportionate contributions to the loss. The responses to this call in the large majority of cases have been promptly made, there is, however, a balance not yet received of $1,717.78.

REORGANIZATION AND FUTURE WORK.

Early in the year, a committee was appointed by the INSTITUTE, consisting of Messrs. C. H. Banes, Chairman, Chas. Bullock, J. Vaughan Merrick, Isaac Norris, Jr., Wm. Sellers, Wm. P. Tatham and John J. Weaver, to take into consideration the future work of the INSTITUTE, and to suggest plans or methods for extension. This committee had a number of meetings, and gave much time and thought to the work entrusted to it. As a result of its report, the INSTITUTE made a number of changes in the By-laws, the most radical of these being the creation of a Board of Trustees, in whom the property of the INSTITUTE shall be vested—the Trustees to be elected, partly by stockholders and partly by the Board of Managers, and to be self-perpetuating. Another important change was made in the manner of selecting the members of the Committee on Science and the Arts. Some valuable suggestions have been made by members of the INSTITUTE in reference to the selection of a proposed site for a new and commodious building suited to its increased library and work.

The movement in this most important matter has been deferred by the Board during the deliberations of the committee, but it is to be hoped may commence at once and be pushed with that intelligence and vigor necessary to command the success it deserves.

Respectfully submitted, C. H. BANES, *President.*

The Committee on Library presented the following report:

THE COMMITTEE ON THE LIBRARY respectfully reports, that the Library of the INSTITUTE has received from the Committee and the Librarian the attention demanded by so valuable a collection of literature pertaining to the arts and sciences. The want of proper space for the classifying and safekeeping of the books has been a source of solicitude to the Committee, and the accumulation of duplicate volumes induced the Committee, during the past year, to print in pamphlet form a complete list of duplicates. This list was distributed widely to libraries throughout the country, and has resulted in effecting the sale of 336 volumes and pamphlets for the sum of $118.15, and the exchange of 1,464 volumes and pamphlets—for 567 volumes and pamphlets,

valued at $466.49. A large number of duplicates yet remains for sale or exchange. The additions to the Library during the past year are as follows:

Volumes, bound,	1,325
Volumes, unbound,	516
Pamphlets,	1,817
Charts and maps,	96
Total,	3,754

Total number of volumes in the Library, exclusive of pamphlets, December 31, 1886, 27,998. The pamphlet collection in the Library is large and valuable, nearly all of them have, during the past year, been classified and arranged in paste-board cases, to admit of more ready reference. The introduction of incandescent electric lights into the Library will, it is hoped, prove acceptable to all who have occasion to use the Library at night.

CHARLES BULLOCK,
Chairman of Committee on Library.

Foregoing reports were accepted and ordered to be placed upon the minutes.

Annual Reports were presented from the Chemical and Electrical Sections, which were accepted and ordered to be filed.

The Secretary presented his report, which comprised an Annual Review of the Progress of the Arts and Manufactures. The report was ordered to be printed, and a copy sent to each member, together with a copy of the Report of the Board of Managers.

The tellers of the Annual Election made their report, whereupon the President declared the following to be elected, as indicated below:

For President, (to serve one year,) JOSEPH M. WILSON; for Vice-President, (to serve three years,) CHARLES BULLOCK; for Secretary, (to serve one year,) WILLIAM H. WAHL; for Treasurer, (to serve one year,) SAMUEL SARTAIN; for Managers, (to serve three years,) CHAS. H. BANES, CYPRIEN CHABOT, WASHINGTON JONES, EDWARD LONGSTRETH, ISAAC NORRIS, JR., ALEX. E. OUTERBRIDGE, THEO. D. RAND, COLEMAN SELLERS; for Auditor, (to serve three years,) WM B. COOPER.

For members of the *Committee on Science and the Arts:*

Bilgram, Hugo, mechanical engineer.
Chambers, Cyrus, machinist.
Chabot, Cyprien, machinist.
Cheney, Luther L., machinist.
D'Auria, Prof. L., civil engineer.
Eastwick, J. H., chemist.
Emanuel, J. M., engineer U. S. N.
Estrada, R , mechanical engineer.
Faught, L. R., machinist.
Gieseler, E. A., light-house engineer.
Greene, Prof. W. H., chemist.
Hill, Rufus, R. R. master mechanic.
Howard, C. W., machinist.
Hall, Prof. L. B., chemist.
Haug, John, marine architect and engineer.
Haupt, Prof. L. M., civil engineer.
Heyl, H. R., machinist.
Ives, F. E., photographer.

Koenig, Prof. Geo. A., metallurgist.
LeClere, Francis, mechanical engineer.
Le Van, W. B., machinist.
Longstreth, Edward, machinist.
McAllister, W. M., optician.
Marks, Prof. Wm. D., mechanical engineer.
McDevitt, Wm., insurance expert.
Marshall, Samuel R., machinist.
Orr, Hector, printer.
Outerbridge, A. E., assayer.
Perkins, Geo. H., oil-refiner.
Pistor, Philip, draughtsman.
Pemberton, H., Jr., Chemist.
Randolph, Prof. N. A., M. D.
Ronaldson, Chas. E., mechanical engineer.
Rutter, Chas. A., draughtsman.
Shaw, Thomas, machinist.
Spellier, Louis H., electric clocks.
Shain, C. J., philosophical instruments.
Scott, E. Alexander, telegrapher.
Salom, Pedro G., chemist.
Sellers, Coleman, mechanical engineer.
Sartain, Samuel, engraver.
Sadtler, Prof. S. P., chemist.
Search, T. C., textile manufacturer.
Wiegand, S. Lloyd, machinist.
Wahl, Dr. Wm. H., Secretary FRANKLIN INSTITUTE.

Whereupon the meeting was adjourned.

WM. H. WAHL, *Secretary*.

BOOK NOTICES.

THE TECHNO-CHEMICAL RECEIPT BOOK. By Wm. T. Brannt, and Wm. H. Wahl, Ph.D., Secretary of the FRANKLIN INSTITUTE, Philadelphia. Henry Carey Baird & Co. London: Sampson Law. 1886. 495 pp.

This work, edited as it is by an able, practical chemist, fills a long-felt want, in that it places before the public, in a reliable and authoritative form, several thousand receipts covering the latest, most important and most useful discoveries in chemical technology and their practical application in the arts and industries.

Dr. Wahl's facile pen has been put to good use in the preparation of such new matter as has been necessitated for the greater usefulness of the book in America, and shows itself in the clear, precise and intelligent directions given in those receipts or processes that he has re-written, as well as in his editorial supervision of the entire work.

Good judgment has been displayed in the omission of the theoretical reasoning and historical detail that are too frequently permitted to encumber works of this character.

The alphabetical index is not alone relied on to enable the reader to intelligently use the work, but is supplemented by an unusually full index as well as a copious table of contents.

We feel confident that the book will be fully appreciated by those to whom it is addressed.

E. J. H.

THE FIGURE OF THE EARTH. By Frank C. Roberts, C.E. Science Series. New York: D. Van Nostrand. 1885. pp. 95.

The object of the publication, as stated in the preface, is to place before

the public valuable historical data relating to the figure of the earth, as well as to arrange in a compact form the more important mathematical principles for the deduction of the figure of the earth upon the spheroidal hypothesis. The book is clearly written and will doubtless prove of value to those interested in the topic to which it relates. E. J. H.

FORESTRY IN NORWAY. By John Croumbie Brown, L.L.D. Edinburgh: Oliver & Boyd. 1884. 227 pp.

This work was put into book-form by the author from a series of popular lectures.

The general interest manifested in intelligent forestry laws has naturally attracted considerable attention to all publications tending to throw light on the same, and we feel assured that the special student of forestry will find in this volume much of interest and value.

Treating, however, as the writer does, of a country rich in the diversity of its physical features, it will probably prove especially interesting, not only to the student of physical geography, but to the general public as well.

The important questions of forest devastation and remedial measures are treated in separate chapters. The feeling as regards the fact of these topics is thus referred to: "Notwithstanding the great recuperative power manifested by Norwegian forests, of which mention has been made, they are, under the excessive drain made upon them in districts favorably situated for the prosecution of trade in timber, being greatly impoverished. Of this, there are indications in more than one of the official reports mentioned in connection with the information given in a previous chapter relative to the geographical distribution of different kinds of trees in Norway."

As to the future, quoting from another publication, the book says: "Large forests cannot be expected in this country, owing to the natural formation, which is mountainous, and greatly intersected by fiords; moreover, the narrow valleys are cultivated, and the mountain-sides often nearly bare rock. The inhabitants are often in want of fuel; turf also being rare. Even in the lower districts, the mountains rise above the forest line, and on the coast the inhabitants and sea-breezes have almost completely destroyed all the forests, which existed in earlier times."

Speaking of remedial measures, the necessity for replanting is of course insisted upon. The cost of fences, in order to protect the young trees from the sheep, is too great in most districts to permit the inhabitants from doing much in this direction. Government aid is therefore requested. E. J. H.

TOPOGRAPHICAL DRAWING, ETC. By Lieut. Henry A. Reed. New York: John Wiley & Sons. 1886.

Here is a work which bears the impress of careful preparation, and, upon examining it, we find it full of the details of the subject of which it treats. It is as complete a treatise on topographical drawing as could be desired by an aspiring student. To the practitioner also it is useful, and would prove an acquisition to his library of reference.

Among other interesting matters, it contains the description of a method

of rapidly coloring topographical sheets, with the object of bringing into relief the shape of the ground. Although this embellishment is not absolutely necessary to enable an engineer to locate a proposed work on a topographical map, yet it helps the operation more than is generally supposed in the profession. Plain contours do not speak clearly to the eye, however useful they may prove to the reasoning faculties; but when they are tinted to proper degrees, the eye and mind work more in harmony. In most offices, the time and expense of finishing a map in style are items of some importance; and seldom is any æsthetic inclination allowed headway. But the rapidity with which topographical maps may be tinted should produce change of opinion in regard to their embellishment.

When the art of surveying shall be better practised among us, and railway and city plans become more accurate, a tendency to embellishment will naturally arise, in virtue of the artistic impulse of humanity to adorn that which is worthy of its respect. Moreover, a certain artistic treatment should always accompany a plan of whatever description. To illustrate: Suppose a map of this state were contemplated, of a scientific character equal to that of the great map of France, would it not be worthy of the most elegant finish? Certainly! On the same principle a *good* map of a large city, and of an important railway, deserves each its special treatment—not of as high quality, probably, as a state map, yet none the less of a pleasing nature.

To the engineer who wishes to carry into effect these ideas, and to look into other interesting points bearing on topographical drawing, we can recommend, without reservation, Lieut. Reed's work. E.

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS AND ASTRONOMY.

RECENT ADVANCES IN METEOROLOGY.—The United States Signal Service merits the thanks of the student of meteorology, by its publication of *Recent Advances in Meteorology*, by William Ferrel, M.A., Ph.D. The volume, 440 pp., is published under the general title, *Annual Report of the Chief Signal Officer of the Army to the Secretary of War.* 1885. Part II. Appendix 71.

The ability with which Dr. Ferrel handles his subject, the clearness and terseness with which he treats it, and the comparatively extended bibliographic research upon which he bases it, will, we think, cause this publication to rank among the most valuable yet issued by the Signal Service.

The volume, as its title indicates, treats of recent advances in meteorology, employing the word recent to embrace those of the last quarter of a century. These advances are presented in logical sequence, and justly entitle the work to be ranked, as its author claims for it in his preface, as "A text-book of the higher meteorology." Where necessary, for the fuller elaboration of some of the topics discussed, the author makes free and extended use of mathematical analysis.

The book is arranged under five chapters, viz.: The Constitution and Physical Properties of the Atmosphere. Chap. II, Temperature of the Atmosphere and Earth's Surface. Chap. III, The General Motions and Pressure of the Atmosphere. Chap. IV, Cyclones. Chap. V, Tornadoes. Each chapter is discussed under numerous sections and sub-sections.

Advances in meteorological science have been so rapid since simultaneous observations, over extended areas, have been made by different Governments, that many of the statements made by Dr. Ferrel, though in reality comparatively old, may nevertheless be novel to many of our readers. We will, therefore, call attention to some of the more interesting of these, without reference to the extent of their claims to novelty.

Departing, however, from the methods usually followed in a review, we will make such condensed statements of meteorological topics treated by the author, or suggested by the context, as we believe may prove of general interest.

The relative proportion of the oxygen and nitrogen of the atmosphere have not varied apparently since the analysis of Regnault, in 1848. The widest variations of the oxygen were included between the limits 20·9 per cent. to 21·0 per cent. The lowest percentage of oxygen—20·3—is found principally in warm climates. The percentage of oxygen is least for the equatorial, and greatest for the polar winds.

A slight decrease exists in the percentage of oxygen in the highest strata of the atmosphere. Only a slightly greater percentage of carbonic acid is found in the air of large cities than in the open country. The proportion does not vary appreciably with the altitude.

Ozone, or tri-atomic oxygen, is to be properly regarded as a general constituent of the atmosphere, since it not only is always to be found in the air, but it also exists therein in measurable quantities.

The arrangement of the constituents of the atmosphere through the agency of diffusion, may be discussed both in accordance with Dalton's theory, and with the kinetic theory of gases. As regards the aqueous vapor of the air, the fact that it is continuously passing from the vaporous to the liquid state, and back again, at different rates, and at different times and places, causes the distribution of this constituent of the atmosphere to be less regular than the other constituents, and leads to grave errors where the amount of aqueous vapor in the atmosphere over extended localities, is deduced from the observed tension at any given locality.

Diffusion according to the kinetic theory of gases is thus lucidly stated. "According to this theory the expansive force and tension of a gas arise from the constant motion and encounters of the molecules flying with great velocity and, on account of the numerous encounters and deflections, in all directions. If the gas is more dense in any region than in neighboring regions, the outward expansive force from this region is greater than the counteracting force toward it, and more molecules pass out than into it, until uniformity of density is established, or, when there is an external force acting in one direction, until an arrangement takes place that makes the tension of all parts exactly equal to the pressure arising from the external force."

The effect, both of Dalton's theory of diffusion, and of the kinetic theory of gases, as regards the final state of the mixture, is the same: the only difference is as to the rates at which the mixture is effected.

Had our atmosphere a constituent of very small density, such for example as hydrogen gas, although the lower strata would contain such rare gas, its tendency would be to rise up far enough above the others so that at certain altitudes it would exist free and separate from all the other constituents. The sun's atmosphere, which, as observed from the earth, consists of nearly pure hydrogen, probably contains in its lower strata an atmosphere of far denser gases.

The diffused light and heat of the sky are due to reflections and re-reflections of the light passing through it. To these irregular reflections are due the visibility of bodies not placed in the direct light, the continuance of twilight, the failure to obtain total darkness at the centre of the shadow during a total eclipse of the sun, and the fact that the greatest cold of the night occurs not directly after midnight but shortly before sunrise.

In clear weather, when the transparency of the air is great, the irregular reflection is small, and the light towards the blue end of the spectrum only is reflected, consequently the color of the sky is a very dark blue. As the atmosphere becomes less transparent, the sky grows first bluish, and afterwards, when all the colors are reflected, of a whitish tinge.

The idea advanced by Tyndall that the diathermancy of the atmosphere is dependent almost entirely on the quantity of aqueous vapor it contains is now to a great extent discredited. The diathermancy would appear to depend not so much on the actual as on the relative humidity, and is greatest when the air is near its point of saturation, whether the actual quantity it then contains is great or small.

Clouds may exist in air unsaturated with moisture if dust-particles be present. The cause is to be ascribed to the lower temperature of the dust-particles due to their higher radiating power than the air, rather than to any affinity or attraction such solid particles have for the vapor.

The great differences in temperatures that would naturally exist between the lower and upper strata of air are lessened by the evaporation of moisture near the surface, which lowers the surface temperature, and its condensation in the upper regions which are thereby heated. Hence the difference between the upper and the surface temperature is less in the equatorial regions where the evaporation and condensation are greatest.

No considerable secular change of temperature appears to have taken place over the earth's general surface for many centuries past. Hence no marked change for extended periods in the intensity of the solar-radiation appears to have been probable. Periodical changes in the sun's surface, however, do occur, and such changes probably influence the mean annual temperature of the earth's surface. Proofs are yet wanting, to show that such periodical changes in the solar-surface, such, for example, as the eleven-year sun-spot period, have produced any appreciable influence on the earth's surface temperature.

Yakutsh, in Siberia, has heretofore been credited with possessing the

lowest mean annual temperature of any explored region of the earth. According to Woeikoff, however, the severity of its winters is far less than that of Werkhojansk, which has an observed mean annual temperature for the month of January of — 55°·2 F. as against — 41°·4 F. for Yakutsh. The excessively low temperature of Werkhojansk is local and extends to but a comparatively limited distance around. Its cause is to be found in the fact, that during calm, clear nights, the valleys are colder than the surrounding high lands, since the cold air sinks down and collects in the valleys.

According to Hamberg, during the night, the temperature of the strata of air very near the earth's surface increases from the surface upwards, and continues to do so until about two hours after sunrise. E. J. H.

THE NUMBER OF STARS IN OUR NEBULA. (*L'Astronomie*, **5**, 406.)—Upon data furnished by observations, M. Gustave Hermite has established two very important laws in regard to the number of stars in our nebula, and the total amount of light we receive from the various classes of stars of different magnitudes.

By the first law, the successive number of stars of first, second, third, etc., magnitudes, follow an increasing geometrical progression of which the first term is 19, and the ratio = 3.

By the second law, the amount of light received from the successive orders of stars of first, second, third, etc., magnitudes, follow also an increasing geometrical progression of which the first term is 19, and the ratio $= \frac{3}{2 \cdot 56}$.

By the aid of these laws, and the assumption that the total amount of light the earth receives from the stars is one-tenth of that of a full moon. M. Hermite concludes that our nebula contains 6,000,000,000 stars. L. d'A.

A. RICCÒ and A. MOSCARI, of the Royal Observatory of Palermo, publish (*Mem. della Soc. degli Spettroscopisti Italiani*, Vol. **15**, *Disp. 7a*), their work on "Determining the Dimensions and Positions of the Solar Protuberances in the years 1882–83–84." "It is highly important," say they, "to determine the law, which the variation of the mean latitude of the solar-protuberances, obeys; also, to see if there is any relation with the period of frequency of solar-protuberances, as well as with the law of Spörer for spots." The short period yet covered does not permit any satisfactory deductions; but this first attempt at accurately stating both the position and size of solar-flames may lead to very important discoveries in solar meteorology. M. B. S.

THE MEAN MINOR PLANET.—A. Svedstrup, under the title "*Les petites planètes entres Mars et Jupiter.*" *Une recherche statistique*), publishes in the *Astronomische Nachrichten*, Nos. 2740–41, the results of a laborious discussion, for which he received the gold medal from the Royal Danish Academy, of the elements of the planet that would on the average represent the Asteroid group. It was Olbers, who first proposed to account for the minor planets by means of the hypothesis of the explosion of a single planet, but the weakness of this hypothesis having been shown, the one now generally adopted is that according to which the small planets are due to simultaneous condensation at several points of the ring or system of rings provided by the

nebular hypothesis. It is with a view both of testing this hypothesis and of throwing light on the geometric arrangement, which the orbits of these small planets present, that a number of statistical researches on the ring constituting the minor planets have been undertaken. D'Arrest found that large eccentricities of orbit were generally combined with great inclinations to the ecliptic; and that the nodes and perihelia seemed to have a tendency to accumulate in certain directions. Newcomb demonstrated the latter as an effect of perturbations. Besides, Kirkwood called attention to the fact that if these planets are grouped according to their mean distances, there will be intervals relatively vacant at such mean distances as to have periods of revolutions in simple ratios to those of the larger planets. Such is in effect a summary of the author's reasons for undertaking the work. For the elements of the mean planet, we must refer to the original article, only stating that the mass assigned would make it of a magnitude of 6·7 in opposition. M. B. S.

ASTRONOMICAL JOURNALS IN AMERICA.—It is gratifying to note that America is once again to have an astronomical periodical, devoted to the advancement of the science itself. We refer to the recent resumption of the publication of the *Astronomical Journal*, by Dr. B. A. Gould. When in July, 1861, the *Journal* was, on account of the war, discontinued with the words: "It is my fervent hope to resume the publication of the *Journal* at an early day, by commencing the seventh volume soon after the suspension of the present insurrection," Dr. Gould could scarcely have imagined that a full quarter of a century would intervene before his "fervent hope" would be realized. It is creditable to his pertinacity of purpose, as well as to his interest in the furtherance of astronomical science, to have again undertaken so important a task. We should remember, too, that the major portion of these years have been given by Dr. Gould to the advancement of American astronomy in connection with the Argentine National Observatory, and in a manner that has challenged the admiration of the scientific world. The long years of experience acquired in the science will no doubt contribute to the character of the *Journal*, and, we hope, secure for it permanence of publication. "The plan," says Dr. Gould, "is to continue the *Journal* in the same form and spirit as before, and under essentially the same conditions. These imply a devotion to the advancement, rather than to the diffusion of astronomical knowledge, yet without disregarding the importance of a prompt announcement of important discoveries. They imply also the dissemination of original researches only, and with the understanding that the publication of statements or opinions is in no case to be interpreted as an endorsement of them by the editor."

It is impossible to estimate the stimulus that a journal of this character may give to astronomical science in this country. It provides a ready means for the publication of researches likely to go unpublished for years, and it will no doubt also encourage researches and valuable observations, which would otherwise not have been undertaken. Surely, with all the big telescopes and observatories of the United States, it should be possible to associate a journal that would reflect a respectable quality of work. We have no doubt,

however, the *Journal* will flourish, notwithstanding the present number of excellent equipments now in almost total disuse, nor that it will stimulate to the provision of a proper staff of observers for them.

The only other American astronomical periodical, dating back to the time when the *Journal* was published, is the *Astronomical Notices* of Brünnow, published first in 1858, from the Observatory at Ann Arbor. While intended to secure the publication of observations and investigations made at that observatory, he also intended it to furnish reliable ephemerides of newly-discovered comets and asteroids, and invited communications from other astronomers. Unfortunately, it also ended its career about the beginning of the war. Some of the numbers are particularly valuable, and we could wish a republication, in some accessible form, of all the matter of the *Astronomical Notices* not positively unserviceable. The *Notices* cannot now, we believe, be had in complete sets, and yet we cannot well afford to lose the important contributions. It may be here remarked that Drs. Gould and Brünnow were both students under the celebrated Encke, and that the lines of active astronomers in America, nurtured into existence by them, can easily be traced. We hope that the early efforts of these men to create an American astronomical literature may not only be not forgotten, but may in some practical way be made accessible.

A more recent effort is the *Sidereal Messenger*, published by Prof. Wm. W. Payne, Director of Carleton College Observatory. It began with a very popular tone and with very little to recommend it to the attention of scientific men. But it has gradually advanced somewhat in the scientific direction, so that it now occupies a fairly respectable position, with the prospect of serving a very useful purpose in American astronomy. The editor certainly deserves the praise and practical sympathy of all interested in the science for securing so creditable result in the face of much indifference.

The only other American astronomical periodical with which we are acquainted is the *Revista do Observatorio*, a monthly publication of the Imperial Observatory of Rio de Janeiro. It is a publication of a semi-popular character—containing an indication of phenomena, popular discussion of astronomical topics, meteorological papers and notices of astronomical events.

M. B. S.

William Huggins (*Astron. Nach.*, **2,747**), formally announces the apparent failure of his method of photographing the solar corona without a solar eclipse. The plates, taken in England about the time of the eclipse of May 6, 1883, presented, he says, not only a general resemblance to those taken during the eclipse, but showed a remarkable rift, which was the main feature of the corona as photographed at Caroline Island. In the eclipse of August 29, 1886, Dr. Gill, of Cape of Good Hope, found that the plates did not show "the corona cut off partially by the moon in its approach to and passage over the sun." Hence, while expressing inability to explain the early favorable results, Huggins states that the method "would seem to have failed."

M. B. S.

CHEMISTRY.

ON THE MAGNETIC ROTATION OF MIXTURES OF WATER WITH SOME OF THE ACIDS OF THE FATTY SERIES, WITH ALCOHOL AND WITH SULPHURIC ACID; AND OBSERVATIONS ON WATER OF CRYSTALLIZATION. By W. H. Perkin. (*Jour. Chem. Soc.*, **49**, 777).—Taking the molecular rotation of water as unity, this value is found not to be the same as the sum of the values of oxygen and two of hydrogen as deduced from the molecular rotation of other compounds. The lowest value for $H_2 + O$ is 0·645, the highest 0·769, instead of 1·0. So that in hydrated compounds the numbers given might indicate whether they still contained water, or whether the water and the substance with which it was mixed had combined to form new compounds. It is known that on adding water in molecular proportions to certain of the fatty acids and alcohols, changes take place in the volume, density and temperature of the mixture; and since it has been believed that some of the fatty acids do unite with water to form tri-hydric alcohols, their examination appeared to be of special interest. The following are some of the results obtained:

	Magnetic Rotation Calculated.		Found.
CH_2O_2,	1·671	2·671	2·666
H_2O,	1·000		
$C_2H_4O_2$,	2·525	3·525	3·554
H_2O,	1·000		
$C_3H_6O_2$,	3·462	4·462	4·512
H_2O,	1·000		
C_2H_6O,	2·780	3·780	3·787
H_2O,	1·000		

From these numbers, it will be seen that these products behave as mixtures of the acids and alcohol and water, and not as though the latter were combined as hydroxyl.

Mixtures of sulphuric acid and water in molecular proportions were now examined, with the following interesting results:

	Calculated.		Found.
Sulphuric acid,	2·315	3·315	3·188
H_2O,	1·000		
Sulphuric acid,	2·315	4·315	4·113
$2H_2O$,	2·000		
Sulphuric acid,	2·315	5·315	5·064
$3H_2O$,	3·000		

The increase in rotation, due to the water added, is in the first case 0·825, in the second 0·925, in the third 0·951, instead of 1·0; hence we have the indication that the largest amount of combination takes place when the first molecule is added, and it would appear that sulphuric acid with one molecule of water forms the compound $(HO)_4SO$, but that all the acid cannot exist as this without the presence of a large amount of water. Subtracting the value of sulphuric acid from the value of sulphuric acid plus three molecules of water, we obtain,

H_2SO_4 } $3H_2O$ }	5·064
H_2SO_4,	2·315
Influence of 3 molecules of water,	2·749

This value is equal to that of two molecules of water + ·749. The author has found that there exists a close analogy between the action of water on an anhydride of a fatty acid and the formation of such a compound as $(HO)_4SO$. Thus:

Rotation of acetic acid	2·525 × 2	= 5·050
Rotation of acetic anhydride		= 4·282
Difference		= 0·768
Rotation of propionic acid	3·462 × 2	= 6·924
Rotation of propionic anhydride		= 6·185
Difference		0·739

Now, it will be seen that these numbers correspond very closely with the residual number obtained above in the case of sulphuric acid, viz., 0749; so that the probability of the compound $(HO)_4SO$, being the result of the addition of water to sulphuric acid, becomes very strong. The author comes to the further conclusion that the relationship of water of crystallization to chemical compounds is purely *physical.* A. G. P.

ON THE ELECTROLYSIS OF HYDROGEN-FLUORIDE AND ON THE PROPERTIES OF FLUORINE. H. Moissan. (*Comptes Rendus*, **103**, 202 and 256.)—Early last summer, the author presented to the Académie des Sciences a memoir showing that hydrogen-fluoride is decomposed by an electric current with disengagement of hydrogen at the negative-pole, while at the positive there appears a gas having new properties. The experiments have been continued with gratifying results.

The hydrogen-fluoride used was prepared by heating potassium and hydrogen double-fluoride in a platinum-retort, and condensing the vapors in a platinum-receiver cooled by ice and salt. The potassium hydrogen-fluoride was prepared by Fremy's method, and carefully dried, first at 100° C., then over sulphuric acid and potassium hydroxide in a vacuum. The sulphuric acid and potash in the receiver were changed every day during a fortnight, the fluoride being pulverized in an iron mortar each time, in order to present new surfaces. When the double fluoride is free from water, it crumbles to a powder much less deliquescent than potassium-fluoride, and may then be used for the preparation of dry hydrogen-fluoride.

The dry double-fluoride is introduced into a thoroughly dry platinum-retort, and gently heated for about an hour to drive off remaining traces of water with the first portions of hydrogen-fluoride that are disengaged. The platinum-receiver is then adapted, and the temperature is raised, not enough, however, to cause a rapid evolution of hydrogen-fluoride; all the hydrogen-fluoride now condenses in the receiver, which is cooled by ice and salt. (*Fig. 1.*)*

* We owe the privilege of using these cuts to the courtesy of *The Electrical World.*

The hydrogen-fluoride is then transferred to the platinum U-tube, in which the electrolysis is to take place, and which is provided with fluor-spar stoppers, through which the electrodes pass, and with a platinum delivery-tube

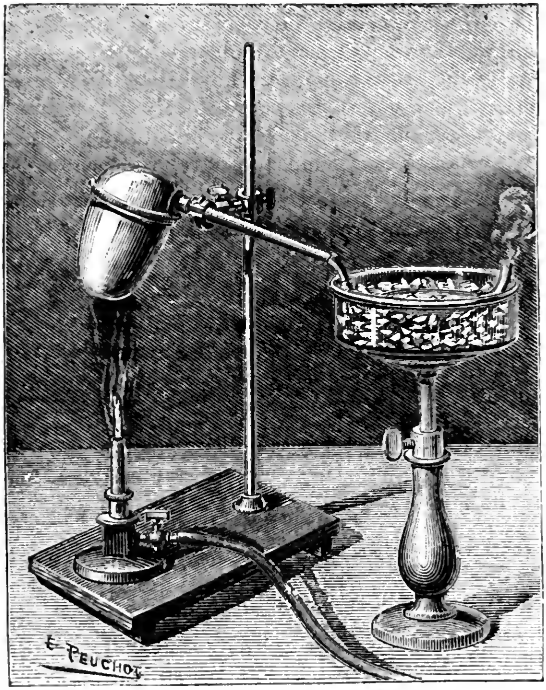

FIG. 1.

on each limb (*Fig. 2*). Both before the introduction of the hydrogen-fluoride and during the electrolysis, this U tube is cooled in a bath of methyl-chloride,

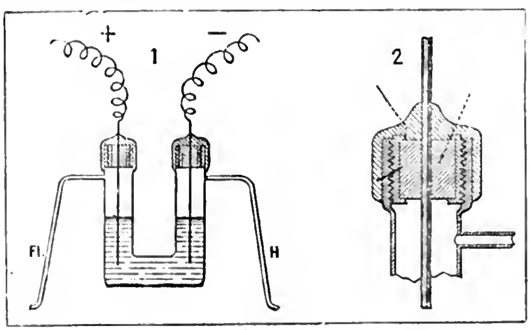

FIG. 2.

boiling quietly at — 23° C. In some experiments, the hydrogen-fluoride was condensed at once in the electrolysis-tube, but as this tube may become

obstructed by the double-fluoride mechanically carried over and dangerous explosions may so occur, this method is not to be recommended. The liquid hydrogen-fluoride may be readily introduced into the U-tube through one of the side-branches.

The current, which served for the decomposition, was derived from a battery of twenty large Bunsen elements, and an ammeter was placed in the circuit. If the hydrogen-fluid contains any water, this is first decomposed, with the evolution of ozone at the positive-pole; but as the last traces of water are decomposed, the resistance of the liquid rises rapidly, and the current of twenty-five ampères is completely arrested when the liquid becomes

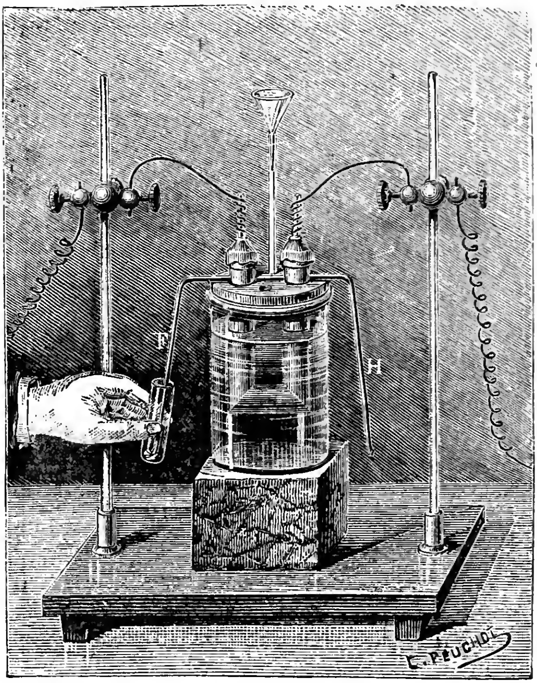

FIG. 3.

anhydrous. The necessary conductivity was given to the hydrogen-fluoride by dissolving in it a small quantity of dry hydrogen and potassium double fluoride. The decomposition then goes on continuously; hydrogen is disengaged at the negative-pole, while at the positive, which is made from an alloy of platinum and iridium, there is set free a colorless gas, in which crystallized silicon burns brilliantly, forming silicon-fluoride (*Fig. 3*). The latter gas was collected over mercury and exactly analyzed.

In the same manner, adamantine boron takes fire, but with more difficulty, probably because of the carbon and aluminium present. Arsenic, antimony, sulphur and iodine combine with the new gas with incandescence,

and water is decomposed by it, with the formation of ozone and hydrofluoric acid. The metals are acted on with less energy, probably because a superficial layer of fluoride is first formed, and this protects the metal from further action; nevertheless, previously-warmed iron and manganese in powder burn with sparks in the gas. Carbon compounds are acted on violently; a piece of cork, held near the delivery-tube from which the gas was escaping, was at once carbonized and inflamed. Alcohol, ether, benzene and turpentine took fire at once on contact with the gas.

When the level of the liquid in the decomposition-tube falls so that the gases are no longer separated, they recombine, even at the low temperature, with a violent explosion.

In order to determine whether the new gas was fluorine or a perfluoride of hydrogen, the delivery-tube from the positive-pole was connected with a platinum-tube containing potassium-fluoride to remove all traces of hydrogen-fluoride, and this with another tube containing a weighed quantity of iron-wire. Arrangements were made for collecting any gas that might escape from the tube containing the iron, and also the gas from the negative-pole. The whole apparatus was then filled with carbon-dioxide, the tube containing the iron was heated to redness, and the electric current was passed while the tube containing the hydrogen-fluoride was cooled to — 50° by forcing a current of air through the bath of methyl-chloride. 0·130 gramme of fluorine was absorbed by the iron, while seventy-eight cubic centimetres of hydrogen escaped from the negative-pole. No gas, except a small quantity of air, could be collected from the tube containing the iron. Since the quantity of iron-fluoride formed corresponded exactly with the quantity of hydrogen collected at the negative-pole, the new gas is unquestionably fluorine.

Operating under favorable conditions, from 1·5 to two litres of fluorine per hour may be obtained by the electrolysis of hydrogen-fluoride.

Fluorine may also be obtained by the electrolysis of potassium and hydrogen double fluoride, fused at 110° C., but the platinum apparatus used is rapidly attacked at this temperature. W. H. G.

Dyes and Coloring Materials of La Plata. (*Textile Manufacturer* **12**, p. 584.)—British Consul Baker, of Buenos Ayres, reporting on the above subject, in addition to an account of several animal and plant dyes, makes special mention of the following wood, which promises to be of value when the resources of that country are developed.

Lapacho (Tecoma asper, Gries). The wood is so hard, that it is used for making cog-wheels.

It contains 7 per cent. tannin, 7·5 per cent. of yellow coloring matter, which crystallizes well, 12·5 per cent. of a less valuable coloring matter which does not crystallize, and 5 per cent. of caoutchouc.

The crystallizable coloring matter, which has been called *lapachic acid*, is prepared by boiling the wood with dilute solution of sodium carbonate, precipitating with hydrochloric acid and purifying by crystallization from alcohol, which leaves it in prismatic crystals, these by sublimation are obtained in form of needles. With stannous chloride, alum or acetate of lead as mordant,

a rose crimson color is produced, with stannic chloride a yellow, and with sulphate of copper, a brown. H. T.

Liquefaction and Solidification of Hydrogen Compounds.—K. Olsewski (*Monatshefte für Chemie*, **7**, 371) has found that *hydrogen-fluoride* solidifies to a white, crystalline mass at — 102°·5 C: The solid melts at — 92·3.

Hydrogen phosphide liquifies at — 90°, and solidifies at — 133·5. The solid melts at — 132·5, and boils at — 85°.

Hydrogen-antimonide, prepared by the action of dilute sulphuric acid on an alloy of two parts antimony and three parts zinc, only the first portions of gas being collected, solidifies at — 91°·5. As the temperature is raised, it begins to decompose between — 65° and — 56°, antimony being deposited on the walls of the tube; at — 18° this decomposition takes place rapidly. It is not then difficult to understand why such small proportions of hydrogen antimonide are obtained at ordinary temperatures. W. H. G.

The Graphic Expression of the Relations Between the Gaseous and Liquid States.—S. V. Wroblewski (*Monatshefte für Chemie*, **7**, 383), proposes for curves of equal density, the co-ordinates being temperatures and pressures, the name *isopyknes*. If a system of isopyknes be drawn for any homogeneous isotropic body, the curves cannot cut one another. Instead of the definition of Andrews, the author proposes that the critical point shall be defined as the critical density, or the smallest density which the substance can have as a liquid. The change of a liquid into a vapor at the critical density cannot take place without an absorption of heat, however small it may be. The disappearance of the meniscus is but an optical phenomenon, showing only that the density of the lower layers of gas is the same as that of the upper layers of liquid, and is not a true index of a critical condition. The paper, which cannot well be condensed, includes the complete isopyknes for carbon dioxide. W. H. G.

On the Constitution of Benzol.—Julius Thomsen (*Berliner Berichte*, **19**, 2,944), reviewing the objections to the heretofore proposed structural formula of benzol, shows that all the conditions of the case, including the addition compounds, are met by a formula in which the six carbon atoms occupy the angular terminations of a regular octohedron. In benzol, the atomic unions would be between the extreme atoms—the terminations of the axes—between two adjacent atoms in opposite pairs in a horizontal plane, and between the adjacent atoms in opposite pairs in each of two vertical planes. Each carbon atom would, therefore, be in relations with that diametrically opposite, with one in the same horizontal plane with itself and the centre, and with one in the same vertical plane with itself and the centre. W. H. G.

A Lecture Thermometer.—F. C. Muller (*Berichte*, **19**, 2,175) recommends a large thermometer filled with sulphuric acid, blackened by a little sugar; sulphuric acid expands regularly, and as its coefficient of expansion is three and one-half times as great as that of mercury slight variations of temperature during experiments may be seen by a large class. Successive spaces of ten degrees of the scale, which is placed back of the thermometer, are differently colored, so that the audience can readily read the level of the acid. W. H. G.

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THE MICROSCOPIC STRUCTURE OF IRON AND STEEL.

BY F. LYNWOOD GARRISON, F.G.S.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, December 10, 1886.*]

LADIES AND GENTLEMEN:—The subject which I am about to bring to your attention to-night, is one of the most interesting developments, which the science of metallurgy has ever made, and although the use of the microscope in the practical metallurgy of iron and steel is yet but in an experimental stage, it promises to increase our knowledge of the properties of metals to a degree that it would be difficult to approximate. Although the ultimate practical value of this subject has been much questioned, one thing is absolutely certain—that with the microscope, we can see vastly more of the structure of the metal than could be seen with the naked eye. We see many things, the existence of which we never before suspected, and, as in the case of the application of chemistry to this same branch of engineering, it is only required that the data so derived should be properly interpreted and applied,

that their practical value may be correctly understood. It has long been a custom amongst persons engaged in the manufacturing of iron and steel, to fracture portions of their product and to examine the fresh surface with a magnifying-glass, or more frequently with the naked eye only, by this means forming some idea of the quality of the metal. These tests were still further elaborated by having the metal surface ground down and etched, and if the etching was very deep, to have prints made from it on paper. Such tests were of course very crude, and at the best, gave only questionable information, as it is sometimes the case that two different pieces of iron or steel, which appear exactly alike to the naked eye, or under a low magnification, will have very different physical properties. It is certainly true, however, that an experienced man can usually judge very correctly the value of a metal by its fracture, but unfortunately such is not always the case, and it is in these instances that the microscope is of value. The study of the microscopic structure of metals, as a scientific pursuit, is a comparatively new one; indeed, this is the first time a lecture has ever been delivered upon it in this country. In view of this circumstance, it might be well to glance at the literature on the subject, that some idea may be formed of the amount of work already done.

Probably the first authenticated publication on the subject was a paper read by Herr Martens, before the Verein zur Beförderung des Gewerbfleisses, of Berlin, about the year 1880. This paper is mostly a description of a number of specimens of iron and steel, the fractured surfaces of spiegeleisen and glass, and of crystallized spiegeleisen, etc. The magnification does not appear to be great, nor do the specimens selected illustrate typical cases. Since that time, Martens has done a large amount of excellent work, which has been published in a number of German journals. After Martens, Dr. H. C. Sorby, of Sheffield, Eng., took up the subject, and embodied his first work in a lecture on the "Microscopical Structure of Iron and Steel." In 1883, this lecture was elaborated by Mr. J. C. Bayles, of New York, and published in a paper in the *Transactions of the American Institute of Mining Engineers.** Owing to the novelty of the subject, and a desire to have it taken up by engineers in this country, he very properly made the paper mostly a description of the methods of preparing and etching the

* Vol. xi, p. 261.

metal, and the proper selection and use of the microscope. A great stimulus has recently been given the subject by the exertions and publications of the well-known metallurgist, Dr. Hermann Wedding, of Berlin, through whose influence a special department has been established for this work at the Royal Experimental Station, in Berlin. During the last two years, a considerable number of papers have appeared in this country and in Europe, and although, like every new branch of scientific research, it has to fight its way before its usefulness is recognized, we have reason to believe that before a great while it will be firmly established as a branch of the metallurgy of iron and steel. As we have just seen, the use of the microscope in studying the structures of metals, is of very recent date. This is probably due to the ignorance of the uses of the microscope amongst metallurgists, and to the mechanical and optical difficulties which stood in the way; besides, as you well know, it has only been within recent years that any science at all has been applied to the manufacture of iron and steel. The mechanical and optical difficulties have, in great measure, been overcome, and since the successful application of photography to microscopical work, little else remains to be desired, except better facilities for the use of high powers and a greater perfection in the preparation of the specimens to be investigated. The use of photography has been an enormous help, as it enables a rapid and accurate registration—so to speak—to be made, of what is seen under the microscope, and with a very small expenditure of time and labor, as is not the case when drawings are made.

One of the aims of this lecture is to interest people sufficiently to take up the subject themselves; it might, therefore, be well before going further, to give a short description of the methods used in preparing the specimens, and the tools ordinarily required for the same.

These tools, under ordinary circumstances, are few in number, quite simple and cheap. The following list will be found to contain about all required, unless very fine and accurate work is desired, in which case, the number and cost of same can be increased indefinitely.

One-half dozen large, coarse files.

One hack-saw, with extra blades.

One-half dozen small drills.

One table-vise.
Several hammers.
Several cold-chisels.
Two pairs of fine steel forceps.
Thick glass-plate (hard-glass).
Three sizes of fine emery (70, 80, 90).
Two whet-stones (fine quality).
One gross of small glass phials.
Paper-labels for same.
Stick of sealing-wax.
Spirit-lamp.
One-half gallon kerosene.
Nest of small beakers.
Wash-bottle.
Evaporating dish (porcelain).
One dozen watch-glasses.

Although a complete chemical laboratory might be used to great advantage, the number and quantity of chemicals actually necessary is very small indeed; hydrochloric, nitric, and acetic acids, and a little ammonia being about all required for most purposes. It would not be possible in the limits of a lecture to more than outline the work necessary to properly prepare specimens of iron and steel for a thorough microscopical examination. We will, therefore, briefly run over the more essential particulars, trusting that, with the list of tools above given, a fair idea of the work required may be obtained. The metal to be tested is first cut into pieces small enough to be conveniently handled upon the stage of the microscope; the standard size adopted by the Royal Experimental Station in Berlin is a short, cylindrical piece of metal about 3/8 inch in length and 5/8 inch in diameter. After the metal has been filed or turned down to a proper size, the surfaces to be etched are carefully filed off with a fine file, and then further ground down on a glass-plate with fine emery. After all the inequalities of the surface are removed, the metal should be carefully polished upon a hard whet-stone, thus removing all the coarser scratches made by the emery. After thoroughly washing and cleaning the specimen, it is ready for etching, which is an exceedingly difficult operation to properly perform. It is best effected with very dilute nitric acid, of about one part acid to

1,000 of water. Dr. Wedding uses platinum chloride, salicylic acid and a mixture of tincture of galls and acetic acid, for coloring the etched surfaces. It may be well to take this opportunity to call more particular attention to the above method of coloring and etching, which is as unique as it is beautiful. After the metal has been etched and treated with the above chemicals, it is carefully heated, whereupon the portions most readily attacked by the acid acquire varying tints, mostly golden-yellow, purple-red, violet, or dark blue. Dr. Wedding claims that the differences of these colors are characteristic of the different elements present in the metal; he fails, however, to prove this statement. The time necessary for the proper etching of specimens varies greatly, according to the quality and chemical composition of the metal. It would therefore be impossible to specify any definite space of time in which the different kinds of metal should be exposed to the solvent action of the acid. Perhaps the best plan to pursue is to remove the specimens, one at a time, from the acid about every half hour, and subject each to a careful examination with a lens or small microscope. After a little experience, one can generally tell when the etching has gone far enough, in which case the specimen is carefully washed, dried, moistened with kerosene, and placed in a tightly corked glass phial until wanted for examination. The easiest way to "mount" the etched specimens is simply to fasten them to ordinary glass microscopic slides with sealing-wax, care being taken that the etched surface be perfectly parallel with the plane of the glass slide, and consequently parallel with the object-glass of the microscope when under examination.

MICROSCOPES.

It would be difficult to say just what kind of microscope would be best adapted for this kind of work, as there is such a great variety of sizes and shapes in the market. As a general rule, however, the simplest in construction, are the best, particularly so for persons unfamiliar with the use of delicate instruments. For general work, and for the proper application of photography, it is important that the microscope shall fulfil the following requirements:

(1.) The stand should be of the best workmanship and material; there should be no "shake" or lateral motion; in the adjustment of the focus, there should be no "lost motion"—that is, the

focus should instantly change with the slightest motion of the milled heads—and for photography, there *must* be a universal joint, for inclination.

(2.) The instrument must be provided with a fine adjustment-screw, with a groove turned in its periphery.

(3.) The mirror under the stage should be so constructed that it can be made to swing over, around, and above the stage, thus affording a means of more intense illumination to the object than otherwise could be obtained with opaque substances. The objectives should be of the very best quality. Experience has shown that it is poor economy to use any others.

There have been several microscopes specially designed for this work, probably the best and most ingenious of which is that used by Martens, of Berlin.* "It consists of an ordinary microscopic tube, fitted with suitable lenses of moderate power, and the novelty consists chiefly in the way it is mounted. It is held above the table by a knee-piece, fitted at each end with a large ball and socket joint, which can, by means of set-screws, be fixed in any desired position, the more delicate adjustments being effected by the usual rack-and-pinion arrangement. The table itself contains a large circular opening, in which rests a half-sphere, the level surface of which seems as an object-table, and by simply turning this sphere, the object can easily be brought into any desired position, so as to get the best inclination for both light and observation. In order to prevent this spherical table from sliding too freely, its surface is wiped over with a little tallow. The makers of this modified instrument are Messrs. Schmidt & Haensch, of Berlin. A plain parallel glass is fitted in front of the object lens, so as to protect it from danger by coming in contact with the object under investigation."

USE OF PHOTOGRAPHY.

One of the great difficulties in all kinds of microscopic work is to illustrate it properly, that others may see on paper what the investigator sees under his instrument. Naturally, the simplest way to effect this would be by means of drawings, but as every microscopist knows, it is an exceedingly difficult, tedious, and by no means accurate way of illustrating. Investigators have, therefore, availed themselves of the recent rapid development of the

* *Iron Age*, November 2, 1882. Vol. xxx, No. 18.

science of photography, and consequently have simplified their work enormously. Of course, photographs are not so clear and distinct as drawings, but, on the other hand, they are obviously more accurate, and can be made at a small cost of time and money. A good negative once obtained, is of far greater value than a drawing, as it can be reproduced an indefinite number of times by means of prints. When a large number of illustrations are wanted, as in printing, electrotypes can readily be made from the negatives by the various photo-engraving processes.

The camera used for microscopical photographing is made especially for the purpose, and differs from the ordinary cameras in

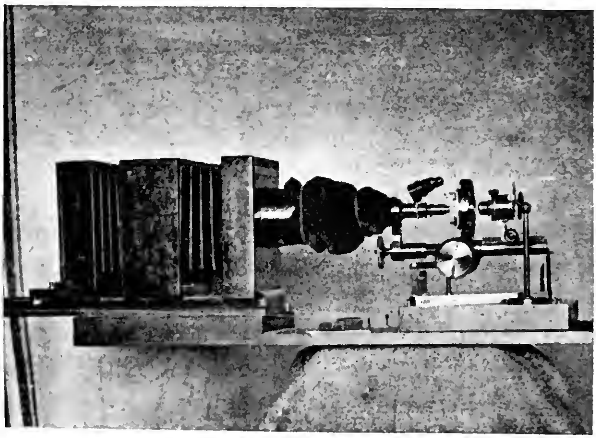

FIG. 1.

having a larger bellows—capable of being extended a couple of feet—and in place of the lens there is a paste-board cone about six inches long, into which the microscope tube is inserted. In *Fig. 1*, is shown the entire apparatus ready for use; the camera and microscope are fastened securely to a long, narrow board made for the purpose, thus giving stability as well as accuracy and convenience to the entire apparatus. The open joint where the camera and microscope are connected, is closely wrapped around with a piece of dark cloth, to prevent any extraneous light from entering. As will be noticed in *Fig. 1*, the camera is small, using a $4\frac{1}{4} \times 5\frac{1}{2}$ inch plate. This size is found by experience to be the most convenient,

and, for most purposes, meets all the requirements of this kind of work. Owing to the difficulty of sufficiently illuminating opaque objects, so as to obtain a good image upon the ground glass, it is very essential that the exposures be made in good, strong sunlight, and that the light be concentrated by some means upon the object. There are a number of instruments which can be used for this purpose, but perhaps the best and simplest is an ordinary bull's-eye condenser. Lamp light is sometimes used, and, when the objects are transparent or translucent, it answers very well, but for opaque objects it is not to be recommended. The sensitive plates should be only of the very best quality, should have great density, and, in short, be as near perfect as possible, besides being as sensitive as they can be made. In concluding my brief summary of the methods of preparation and treatment of the different kinds of iron and steel to be investigated, I should remind you that if success in this, as in all other kinds of scientific research work, is desired, the student must needs have plenty of patience, and use the greatest care in the pursuit of his work. He should not depend much upon the work of others, but take up and study each and every detail for himself. His work would then be of value as original, and unbiased by the opinions and theories of others.

WE WILL NOW TAKE UP the microscopic structure of the different varieties of iron and steel in detail, referring here and there to their different chemical and physical properties, that the variations and peculiarities of structure which they exhibit may be better understood.

As pig and cast iron are probably the most common and useful varieties, we will consider them first. Pig iron, as is well known, is divided into three classes, determined by the color of the metal, which is due almost entirely to the varying amounts of graphitic carbon present: gray iron, containing the most; then mottled; and, lastly, white, which contains hardly any at all. Carbon is usually present in all kinds of iron and steel in two conditions; namely, as combined or amorphous, and as graphite. There is very possibly a third condition, but as its existence is by no means proved, we will therefore not consider it. Upon the total amount of carbon, and upon the relative amounts of the two conditions in which it is

present, depends in great measure the quality of the metal, and the essential difference between iron and steel. It is very difficult to draw the line sharply between iron and steel, or between steel and wrought iron ; but for ordinary purposes, if the metal contain from 1·5 to 4·5 per cent. *total* carbon, it may be considered as cast or pig iron ; from 0·15 to 1·5 per cent., as steel ; and from 0 to 0·15 per cent., as wrought iron.

Gray pig, or cast iron, to the naked eye, has a grayish-white to a black appearance ; sometimes lustrous, by reason of the large size of the graphite flakes or patches. It is usually hard, brittle, and, when of good quality, quite tough If an excess of graphite is present, it is apt to be so soft as to be worthless ; other things being equal, if it contains less than 3·5 per cent. of total carbon, it is pretty sure to be of good quality. Its specific gravity is about 7·1, and its other physical properties variable and dependent upon its chemical composition. In *Fig. 2*, is shown the structure of gray coke pig iron (No. 2), as seen under the microscope with a magnification of fifty diameters The structure shown, is that characteristic of all good qualities of gray pig or cast iron, the shaded lines and patches being the graphitic carbon, which is always prominent in good iron and becomes less so as the metal deteriorates in quality. The surrounding metallic mass presents a compact, granular, non-crystalline structure, frequently containing cavities, due to occluded gases or air. Sometimes the graphite appears to group itself in clusters, or knots ; especially if the quality of the metal is inferior, there seems to be a decided tendency for these graphite flakes or patches to form in this manner. Of course, small cavities caused by gas or air may easily be mistaken for graphite, in a hasty or superficial examination, but with a little care and careful focussing, the difference can readily be detected.

Fig. 3 exhibits the structure of mottled-iron, the mottled aspect to the naked eye is not apparent under the microscope. It will be noticed that the quantity of graphite in this metal is not so great as in the gray iron, and that it appears to be more leafy and more in patches. With a high magnification, however, the little worm-like graphite plates, which are undistinguishable in the illustration, can easily be detected. As we have seen, the larger sizes of these plates are quite characteristic of the gray iron, but such can hardly be said to be the case in mottled iron, as they are

too minute. In mottled iron, it would, therefore, seem that the graphite is not only less in quantity than in the gray, but also that it is in a much finer state of division, although, of course, there are intermediate grades in which these conditions do not exist. To what the mottled appearance to the naked eye is due, it would be difficult to determine; it may possibly be caused by the uneven distribution of the graphite. Some grades are nothing but mixtures of gray and white iron, hence the mottled appearance can easily be accounted for. In *Fig. 4*, we have shown the structure of white pig, or cast iron; its structure, both under the microscope and to the naked eye, being distinctly crystalline. The intensity of the crystallization depends very much upon the degree of chilling, there being substantially no difference between chilled and white iron. In a large casting made in a metallic mould, the outer surface, which comes in contact with the mould, will be found to exhibit a highly crystalline structure (as shown in *Fig. 4*), while the inner part, which has cooled more slowly, will show little or no crystalline structure. One peculiarity of chilled iron is, that the crystals are always arranged with their axes normal to the surfaces of the mould. When magnified to a comparatively high degree, the metal appears deeply furrowed, these furrows running parallel to the long axes of the crystals and appearing to separate them. I have never been able to detect any graphite plates in white iron, although there may possibly be a very few in some grades of the metal. The dark-shaded places, noticed in *Fig. 4*, are caused by the furrows between the crystals.

White or chilled iron is harder than the hardest kind of steel; it is brittle and difficult to work. Its principal use is for the treads of car-wheels, and recently, I have been informed, it has been used with great success for machine tools.

WROUGHT IRON.

Like cast iron, wrought iron may be classified under three heads; namely, forged, rolled and drawn. If we take a piece of wrought iron and fracture it by bending it back and forth, we will notice that it is built up of separate laminæ and fibres. If the metal has been rolled, or drawn, we find the fibres parallel and running in the direction in which the metal has been rolled.

In *Figs. 5* and *6*, we have a longitudinal and a cross section of

such—of rolled iron, as it appears under the microscope. In *Fig. 5*, the parallel fibres spoken of, are very distinct, the dark-shaded parts being cavities containing intermingled slag. It is impossible to obtain any wrought iron in which slag or other impurities cannot be detected by the microscope. In *Fig. 6*, a cross section of the same piece, the fibres are seen on end, as it were, the deeply-shaded parts being cross sections of the slag cavities, seen in *Fig. 5*. There is no trace of crystalline structure, ordinarily, in wrought iron, and I doubt very much if its structure can be crystallized by strains, vibrations, or shocks. I have seen many instances in which wrought iron was said to have been so changed; but on investigation, I was never able to prove that it had been, or that the crystalline structure seen on the fractured surfaces, had not been there before the rupture took place. It is true that iron bars will sometimes snap right off in a most unaccountable manner, and the fractured surfaces have a crystalline appearance, but after a most careful examination of such specimens with the microscope, I have been unable to detect the slightest trace of a *true* crystalline structure.

The fibres, or laminæ, of the metal seem to be suddenly snapped in twain, showing no trace of stretching or bending, and the fractured surface is smooth with a crystalline *appearance*. On close examination with the microscope, however, this crystalline appearance disappears, and the fractured surfaces show the fibrous structure "on end," as it appears in *Fig. 6*. The structure of drawn malleable iron is essentially the same as in the illustrations (*Figs. 5* and *6*), the fibres, or laminæ, being drawn out parallel to each other, instead of rolled. In forged iron, the conditions are altogether different, the fibres being knit or welded together. In *Fig. 7*, which shows the structure of a weld of iron and steel, this structure is fairly well defined; as the magnification, however, is necessarily low, the fibrous structure is not as well shown as could be desired. The granular portions of the metal, which can be readily distinguished, running through the centre of the cut, are due to the steel present, which has not been altered by the forging. If the illustration be examined with care, it will be noticed how closely the two metals are knit together. The cavities (shown by the shaded places) are due to imperfect forging and to the presence of cinder or oxide of iron (scale). The quality of the metal

obviously depends as much upon the perfection with which the fibres are knit together as upon anything else; hence it is important that these impurities should be eradicated as far as possible, for if not, they are apt to become worked between the fibres and prevent their being closely united. It is practically impossible to obtain any forging, however perfect, altogether free from these foreign substances, unless some means to prevent the formation of scale or oxide can be devised. Of course, this amount can be reduced to a minimum by thorough and careful forging.

STEEL.

The rapid growth of our steel industries, and the enormous extent with which steel is being employed in the arts, renders it imperative that our knowledge of the properties of this great metal should be more perfectly known. That as yet we know very little about them, every metallurgist and iron manufacturer will tell you, and the wonder is that we are able to make steel as good and as cheaply as we do. Chemistry and the testing machine have doubtless taught us much, and probably will teach us much more, but it seems eminently desirable that some new and other means be obtained, wherewith we can learn more of the physical properties, minute structure, and peculiarities of both iron and steel. That the microscope will, to a considerable extent, supply these wants I am well assured, and I trust that before I finish my lecture, you will agree with me. As you all know, there are two kinds of steel, hard and soft, each being made in an entirely different manner. The hard or tool steel, is usually made in small crucibles, while the soft or malleable steel is made in the Bessemer converter, the open-hearth, or by some other pneumatic process. The microscopic structure of hard or tool steel is very simple, as will be seen in *Fig. 8*. It is hard, compact and granular, very rarely containing any impurities, such as slag, cinders, or oxide of iron. This hard granular structure is usually regarded as crystalline, and, to the naked eye, it frequently does appear as such. As will be noticed in *Fig. 8*, it is truly granular without a trace of crystalline structure. The amount of carbon in tool steel varies according to the temper from about 1·15 to 1·50 per cent—this, of course is combined, as there is ordinarily but a trace of graphitic carbon present. Its specific gravity is about 7 90.

There is practically no apparent structural difference in the various grades of tool steel, except that the grains, or granular structure, is larger or smaller as the case may be. As a general rule, the finer the grain, the harder the metal, and the greater the amount of carbon it contains. Except a small quantity made by methods in use many years, the great bulk of the soft steel now used is made either by the Bessemer or the open-hearth process; it is with these latter, therefore, we have to deal. There should be theoretically no difference in the product of these two processes, but, as a matter of fact, there almost always is not only a little, but a considerable difference. The product of the open-hearth furnace is usually much superior in every way to that of the Bessemer, and as its operations require much more skill and care, its cost is proportionally greater. Its use is chiefly for purposes where high tensile strength and elasticity are required, as in boilers, fire-boxes, ship-plates, etc.

As the general microscopic structure of open-hearth steel is very similar to that of the Bessemer steel, we may leave its consideration for another opportunity, and continue with the latter. Bessemer steel is produced from cast iron, by the combustion and consequent removal of some of its carbon. This is effected in what is known as a "converter," which may be described as a huge crucible, through the bottom of which a strong blast of air is forced. After the molten metal has been blown from twenty to twenty-five minutes, and the proper stage of decarbonization reached, the blast is shut off, and a certain amount of highly-manganiferous cast iron run into the converter. This metal is known as ferro-manganese, or, when containing a smaller amount of manganese, as spiegeleisen. It is added to replace a certain amount of carbon removed from the blown metal, and to add manganese to the steel, which is supposed to greatly increase its strength and durability. The metal (steel) is then poured into a large ladle and cast into ingots, which are reheated and rolled into rails. The greatest difficulty encountered in this process, is to obtain a uniform product and homogeneity of the metallic mass; the former is ordinarily obtained, but the latter rarely indeed, and, as far as my experience goes with steel rails, it is never obtained. In *Figs. 9* and *10*, we have respectively a longitudinal- and cross-section of a bolt made of Bessemer steel, the structure shown here being

decidedly "steely," having the characteristic compact and granular appearance of steel. As in former cases, the shaded parts are due to cavities and furrows, but these are caused, however, not so much by intermingled slag and other impurities, as by gas and air cavities in the ingots. When the ingot is rolled, these cavities, of course, are elongated into furrows as in *Fig. 9*. Some idea of the vast number of such cavities and furrows can be formed by examining *Fig. 10*, which shows those of the previous figures "on end." Such imperfections cannot but be detrimental to the strength and durability of the metal. There is probably no department of metallurgy in which the microscope can be used to greater advantage than in the study of the minute structure of steel rails, and there is certainly none upon which we need more information. It was with this end in view that I took up the work a short time ago. The results obtained have so far been eminently satisfactory to myself, although as yet but a very small amount of work has been accomplished. Enough, however, has been done to convince me of the great lack of uniformity and homogeneity of Bessemer steel, as it is ordinarily produced.

In making microscopic examinations of a steel rail, a section about a half inch thick, should be cut from the middle of the rail. The section should then be divided into small pieces about an inch square, so as to show as far as possible the structure of the different parts of the rail. These pieces should be equally divided into longitudinal- and cross-sections, for by this means a very good idea of the structure of the entire rail can be obtained. The difference of structure in the head, web and flanges should be carefully noted. In *Fig. 11*, we have a cross-section from the head of a sixty-seven pound (sixty-seven pounds per yard in weight) steel rail, which had been in use nearly ten years. Its structure has the same granular characteristics always found in steel, but, unlike the best qualities of that metal, its structure is *irregular*, some portions being softer and much more easily attacked by the etching acid. These soft places are indicated in the illustration, by the dark shaded patches or blotches. They are probably caused either by an irregularity of chemical composition, or by some mechanical defect in manufacturing; though just what the defect is due to, it would be difficult to say, since it may be derived from a

variety of causes. * In the year 1880, Herr Martens, the well-known engineer and microscopist, noticed similar defects in the steel rail in use in Germany, and in the article referred to, which he wrote at that time, he attributes them to the rolling out of the blisters or gas cavities which were originally in the ingot. He contends that with even the most careful working, it is doubtful if they can be entirely eradicated, and that, although steel containing a large number of them, will sometimes have a high tensile strength, their presence cannot but be detrimental. The illustrations which he gives with his paper, show a structure almost exactly the same as ours. In *Fig. 12*, we have a longitudinal section taken from the head of a sixty-eight pound rail in use six years. Passing directly through the characteristic compact granular structure of the steel, we will notice a large streak of metal, which appears to have been affected to a much greater degree by the acid than the bulk of metal. In this case, as in the cross section, it is probably caused by the rolling out of blisters, gas cavities, or to soft places in the metal, due to an irregular chemical composition.

We have now hastily examined the structure of the more important varieties of iron and steel, we have noted their structure, and the characteristic differences between each. It therefore only remains for me to impress the fact upon you, that each of these varieties constitutes a separate field of research within itself; indeed, the metallurgy of iron and steel itself is so divided up, that one man is a specialist in pig iron, another in wrought, still another in steel, and so on; to thoroughly understand it, each must make a scientific study of his specialty. If the use of the microscope can aid him in this work, and thereby enable him to produce a better product, enriching himself and the world besides, I shall feel abundantly repaid for the hard work I have had in endeavoring to introduce this instrument into metallurgy as an instrument of research.

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* *Glasers' Annalen für Gewerbe und Bauwesen.* December 15, 1880. No. 84, p. 476.

THERMODYNAMICS.

BY PROFESSOR DE VOLSON WOOD.

(*Continued from page 140.*)

This rate, then, involves the imperfection of the gas. We will attempt a more general explanation. The higher an imperfect fluid is heated at a constant volume, the more nearly will it approach to the condition of a perfect gas. Thus, in the equation before given

$$p v = R \tau - \frac{a}{v} - \frac{a}{v \tau} - etc.$$

the larger τ is, the more nearly does $p v = R \tau$; and, conversely, the less τ is the more imperfect is the fluid, and p increases less for a given increase of τ than if it were a perfect gas. Hence, between τ small and τ large, p must increase more rapidly for an imperfect than for a perfect fluid. This granted, it follows that the rate $\frac{d p}{d \tau}$, or $\frac{d p}{d Q}$, is greater for an imperfect than for a perfect fluid, other conditions being the same, as already shown by the equation above. This being the virtual increase of the pressure for one degree of temperature, and the rate being maintained constant at the temperature τ by the absorption of heat, and since all the heat absorbed must have Q units of heat and is transmuted into work at that heat, the virtual pressure during the expansion $d v$ will be Q times the above rate, or

$$Q \frac{d p}{d Q} = \tau \frac{d p}{d \tau},$$

hence, the total work, both external and internal, for the isothermal expansion $d v$ will be

$$d W = \tau \frac{d p}{d \tau} d v$$

and for an isothermal expansion from v_1 to v_2,

$$W = \int_{v_2}^{v_1} \tau \frac{d p}{d \tau} d v = \tau \int_{v_2}^{v_1} \frac{d p}{d \tau} d v. \qquad (11)$$

So much for the analysis and the symbolic representation of the

second law. As we have made no reference, thus far, to that law, the question may be asked: What is its use? Why not dispense with it? There is an advantage in stating the fundamental principles of a science in the form of laws. They are like the foundation-stones of an edifice, they show on what the structure rests. Subjects may be developed in accordance with fundamental principles without statements of formal laws. Newton's three laws of motion have served, and continue to serve, a good purpose in the development of mechanics. The science of thermodynamics is developed by some writers without a reference to a second law, or even the formal statement of any laws. The first law is an expression of the equivalence of heat and work. The second law is an expression for the total work deduced from the external during an isothermal expansion. Let the point be emphasized that the kinetic energy—the heat energy—of a pound of a fluid, or of any given mass of it, depends directly upon its absolute temperature, so that if the latter be maintained constant during a change of volume, the heat-energy will be constant. This can be proved directly for perfect gases, and is believed to be true for imperfect ones, at least in a constant state of aggregation.

We now examine the wording and the meaning of Rankine's second law, as quoted in the early part of this paper. This is the law that Maxwell pronounced "inscrutable." Rankine made several statements of this law, including symbolic expressions of it, but they do not all cover the same ground. Some intensify one point and some another, but they do not antagonize each other, and must be considered as containing a common principle, and if any one of the statements does not cover all the principles necessary for the establishment of the analysis, it must be considered defective or incomplete; otherwise there would be several different laws all claiming to be the second. Rankine expressly states that these several statements are intended to be essentially the same.

According to the symbolic expression already investigated above, the law must contain the idea of isothermal expansion. Certainly, the law contains no such statement explicitly, and if found there at all, it must be in the words "causing work to be performed;" and in order that these words shall convey this idea, it must be considered that neither the substance nor the heat in the substance does the work, but that it is merely an agent for

transmitting the heat from the source to the working-piston, or to some other potential form. But there is no intimation that there is a source of heat, and since this is a necessity, it must be inferred on account of the conditions of the problem; and the temperature of the source must be at least as high as that of the substance. The principle contained in this last statement is sometimes referred to as the second law, viz.: "that heat cannot of itself pass from a body of a lower temperature to one of a higher;" but most writers, especially Rankine and Thomson, consider this as an axiom, and make the second law include a measurable quantity. A source of heat, then, is a necessity, and must be understood in Rankine's second law; or, we might say, as before stated, that the fact of a constant temperature must be admitted, for otherwise the law does not furnish a foundation for the analysis. It will be admitted that the interpretation we have given of this part of the law is somewhat forced; that naturally the words will not convey the idea which we have imputed to them; and that it may be questionable whether they should be so understood; but if not, then the statement of the law is incomplete in this particular. Either the "scope" of the words must be very large, or more words are needed. Rankine, in one of his original papers, supplied the necessary words in a sentence which is so clearly and fully expressed that we copy it, italicizing a part of it:

"Let us conceive that unity of weight of any substance occupying the bulk V under the pressure P, and possessing the absolute quantity of thermometric heat, whose mechanical equivalent is Q, undergoes the indefinitely small increase of volume $d\,V$; and let us investigate how much heat becomes latent, or is converted into expansive power during this process, *the thermometric heat being maintained constant, so that the heat which disappears must be supplied from some external source.*"—(*Misc. Sc. Papers, p. 311.*)

If the "disappearance of heat" in the quotation near the beginning of this article is the same as "*the heat which disappears*" in this last quotation, as it ought to be, we see no good reason for retaining the words "of this" in the former quotation. To retain them, only compels a forced and awkward repetition.

The italicized words contain a principle which should be included in the second law, if it is to furnish a complete foundation for the symbolic expression. Next, consider the expression, "The

total actual heat." This is simply the heat which remains in the body as heat; it is not the heat absorbed by the body, for such heat may have been expended in doing external work, in which case it is no longer heat, none of it being retained as heat; or some of it may have been expended in effecting molecular changes of some kind, called internal work, in which case so much of the heat disappearing in this potential form is no longer heat, although its effect remains in the body. All the heat absorbed by the body remaining after deducting all that has been changed to potential energy is "actual heat" or "total actual heat," it is sensible or thermometric heat. The law states: "If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any number of equal parts," etc. The divisions here mentioned may be conceived as produced in two distinct ways, first, by dividing the substance into equal parts, which, in the case of a uniformly hot, homogeneous substance, will divide the heat into the same number of equal parts, and each part will have the same temperature, and secondly, by conceiving the heat in the entire substance to be produced by equal increments beginning with zero heat. There is nothing in the nature of the case, nor in the language of the author, up to this point, that compels the acceptance of one of these modes of division to the exclusion of the other, and hence the one which will furnish the clearest explanation of the solution sought, will naturally be accepted. For this reason, we conceive that the heat is divided by dividing the mass of the substance. For the sake of greater definiteness, conceive that the substance is in an ordinary steam cylinder, and that it is divided into an indefinite number of prisms having their basis against the piston at one end and the head at the other. The heat of the substance being Q, the amount in each small prism will be $d\ Q$, when the prisms are indefinitely small, and the number of such prisms will be

$$\frac{Q}{dQ};$$

and the amount of work which each can do by expanding an amount $d\ v$, the thermometric heat, Q, being maintained constant, will be

$$\frac{d\ p}{d\ Q}\, d\ Q\ d\ v,$$

and since all those parts are not only equal but altogether alike in nature and similarly circumstanced, their effects must be equal, therefore the entire energy must be the effect of one of the parts multiplied by the number of parts, or

$$\frac{Q}{d\ Q} \times \frac{d\ p}{dQ}\ d\ Q\ d\ v = Q\ \frac{d\ p}{dQ}\ d\ v,$$

which is the symbolic expression of the second law. It may be noticed that this process is slightly different from that in the text, for there the factor $d\ Q$ is integrated, while here it is cancelled in the operation of multiplying, but the results are the same. The fact is, we have here followed the precise process, amounting to nearly a literal quotation, of the author in his original paper, read January 5, 1853 (*Misc. Sc. Papers*, p. 204).

As to the other mode of division, that by increments of heat, it will lead to the same result by a deduction from the former by making the increments of heat, $d\ Q$, the same in value as the heat in one of the small prisms. It needs no argument to show that this is possible, and hence, numerically, the value of the last expression will not be changed by this mode of division. But as an independent proposition, it raises this vital question—does an element of heat, $d\ Q$, low down in the scale, say, for instance, at $\frac{1}{4}\ Q$, cause the same work as the last $d\ Q$ when the heat becomes Q, and if not, how can it be said that "the effect of each of those parts in causing work to be performed is equal?" This mode of division gives a scale of temperature, and so we repeat the question in this form: Is it plain that an increment of heat, $d\ \tau$, will cause the same work to be performed by a pound of gas when the temperature is $\frac{1}{4}\ \tau$, as when it is τ? It can easily be shown to be true for perfect gases in which increments of pressure vary directly as the increments of temperature, and in which also the total work is external, but can it be asserted as equally true for imperfect gases? Before we complete this discussion, these questions will be definitely answered and the obscurity, if any, in regard to the proper mode of dividing the heat into equal parts, will be removed.

As a consequence of the relation between the sensible heat and temperature, we have directly

$$\frac{d\ Q}{Q} = \frac{d\ \tau}{\tau},$$

thus reducing the former expression to

$$\tau \frac{d\, p}{d\, \tau}\, d\, v$$

The last expression has been established in a variety of ways. M. Clausius, Thomson and Joule first considered it in the form

$$\varphi\,(\tau)\,\frac{d\, p}{d\, \tau}\, d\, v,$$

in which $\varphi\,(\tau)$ was an unknown function, to be determined by experiment, and it was so determined by Joule and Thomson, as recorded in Thomson's *Mathematical and Physical Papers*. M. Mayer assumed it to be simply the absolute temperature itself; while Rankine, from his hypothesis of molecular vortices, deduced the form,

$$\varphi\,(\tau) = \tau - \varkappa,$$

$\varkappa$ being the absolute temperature on the perfect gas-thermometer corresponding to the total privation of heat, whose value is very small—at first found to be about 2·1° C.—but after the experiments of Thomson and Joule, with the porous plug, it was found that the error resulting from considering $\varkappa = 0$ would be less than those resulting from the errors of observation, since which it has been considered as zero, and we have

$$\varphi\,(\tau) = \tau,$$

and to this expression Thomson has given the name "Carnot's function." Knowing this result, as Rankine did when he wrote his *Manual*, he assumed it, and so greatly abbreviated the investigation. In regard to expression $Q = k\,\tau$, Rankine remarks, at the close of his celebrated paper "On the Geometrical Representation of the Expansive Action of Heat," (*Trans. Roy. Soc.*, 1854; *Misc. Sc. Papers*, p. 409.) that it is a hypothetical principle, "and that, although existing experimental data may not be adequate to verify this principle precisely, they are still sufficient to prove that it is near enough to the truth for all purposes connected with thermodynamic engines, and to afford a strong probability that it is an exact law." This conclusion has been verified in many ways within the ranges of temperatures used in ordinary practice.

Rankine gives two other statements of the second law in the *Manual*, one expressed in regard to absolute temperature graphi-

cally expressed, the symbolic expression of which, $\tau \frac{d\,p}{d\,\tau}\,d\,v$, is the one most frequently used; the other, a functional relation, which results in the same value as that just given. In his other writings, are several other statements; for instance, in the *Engineer*, of June 28, 1867, is the following:

"If the substance which does the work in a perfect heat-engine receives all the heat expended at one fixed temperature, and gives out all the heat which remains unconverted into work at a lower fixed temperature, the fraction of the whole heat expended, which is converted into external work, is expressed by dividing the difference between those temperatures by the higher of them, reckoned from the absolute zero. Now this is, in fact, the second law of thermodynamics expressed in other words." (See also *Misc. Sc. Papers*, p. 436.)

Yes! exclaims the student, "in other words" this statement is explicit and easily understood, but one does not recognize it as the equivalent of that in the *Manual*. *This* is a mere ratio, *that* the measure of a quantity; *this* is the fraction of the whole heat converted into external work, *that* a measure of both external and internal. The statement includes isothermal expansion, and, taken as a whole, may be made the basis of an analysis for producing the expression $\tau \frac{d\,p}{d\,\tau}\,d\,v$. This is the principle used by Clausius, Thomson, and other writers, for deducing the symbolic expression; and it is probable, if not certain, that Rankine had this operation in mind when he wrote the various expressions for the second law.

Again, in the same article referred to above, is another expression, as follows: "That law (the second) is capable of being expressed in a variety of forms, expressed in different words, although virtually equivalent to each other. The most convenient form for the present purpose appears to be the following:

To find the whole work, internal and external, multiply the absolute temperature at which the change of dimensions takes place, by the rate per degree at which the external work is varied by a small variation of the temperature."

This is explicit, but with the exception of the first eight words, it is merely substituting words for the algebraic expression

$$\tau \frac{d^2 U}{d \tau} = \tau \frac{d p d v}{d \tau} = \tau \frac{d p}{d \tau} d v.$$

Isothermal expansion is asserted in the words, "the absolute temperature *at* which the change of dimensions takes place." The change takes place *at* a constant temperature. Here, the author explicitly states that the work done during isothermal expansion includes the internal work, and the same fact may be inferred from other parts of his writings. According to the last quotation, it follows that any statement of principles, which is sufficient for the establishment of the expression $\tau \frac{d p}{d \tau} d v$ may be considered as the second law. Laws forming the foundation of a science should be simple, explicit, avoiding ambiguity, and complete in their assertions. The one we are considering does not conform to these conditions, and is at best only a remote suggestion of a physical operation. We propose to amplify it, so as to make it include all the principles necessary for the establishment of the symbolic expression, using substantially the language of the author as found in different parts of his writings, as follows:

SECOND LAW.—*If work is done by the expansion of a homogeneous and uniformly hot substance, the thermometric heat being maintained constant by a supply from an external source, and the total actual heat be conceived to be divided into any number of indefinitely small parts, each of the parts being not only equal, but altogether alike and similarly circumstanced, their effects in causing work to be performed will be equal; the total work performed being the external and internal during the expansion.*

I would substitute for all these, and other expressions, a principle common to all of them, and common also to the corresponding principles in the writings of Thomson and Clausius, as follows:

SECOND LAW.—*The work, both external and internal, done during the expansion of a substance at constant temperature, equals the heat absorbed.*

When thus stated, the analyst is free to choose his own method of determining the heat absorbed during isothermal expansion, and when found, the law states that it equals the work done during the absorption. One way of determining the heat absorbed is as follows:

Let a substance capable of indefinite expansion, whose initial volume is $o\,v_1 = v_1$, *Fig. 2*, and pressure $v_1\ A = p$; expand at constant temperature τ, from $o\,v_1$ to $o\,v_2 = v_2$; then will the locus $A\ B$ of the upper ends of the ordinates representing pressures, be an isothermal line. Through A pass the adiabatic $M\ A$, and through B the adiabatic $B\ N$, then if the adiabatics be indefinitely extended, they will be asymptotes to $o\ x$, and the indefinitely extended area $M\ A\ B\ N$ will be the heat absorbed during the expansion from v_1 to v_2. To find this area, conceive it to be intersected by isothermals differing from each other by $d\ \tau$, then will the number of strips be $\frac{\tau}{d\,\tau}$. The area of these strips will equal each other. To prove this, we use Thomson's absolute scale of temperatures. Conceive that the substance after expanding to B expands without transmission of heat until the temperature falls $d\ \tau$, the pressure will fall until

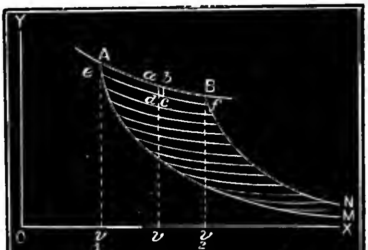

FIG. 2

it reaches the consecutive isothermal $f\ e$; then compress the substance along $f\ e$ isothermally, during which operation heat will be rejected by the substance, the amount of rejection being represented by the area $M\,e\,f\,N$, then compress the substance without transmission of heat adiabatically along $e\ A$ to A. The resultant work will be represented by the area $A\ B\ f\ e$, and this also represents the heat which disappears by this operation.

Now, if when B is reached, the expansion be prolonged adiabatically until the temperature falls $2\ d\ \tau$, the pressure will fall until it reaches the second isothermal, then compress along the second isothermal until $M\ A$ is reached, then compress adiabatically to A. Since no heat is lost along the adiabatics, but all that is lost is along the isothermals, twice the heat will have been abstracted in the second as in the first operation, and the area of the

two strips will be twice that of the upper one. Proceeding in this manner we show that all the strips are equal, so that the area of any one multiplied by the entire number, will give the entire area $M\,A\,B\,N$. In the case of perfect gases, it is easy to find the area of any one of the strips, for the equation to the adiabatics are known, but generally, it is easiest to find the area of the topmost strip, where p and v are known. At any point a in $A\,b$ draw the vertical $a\,d$ to the next isothermal, and construct the vanishing parallelogram $a\,d\,c\,b$; its area will be $d\,p\,d\,v$, and the area

$$A\,B\,f\,e = \int_{v_1}^{v_2} d\,p\,d\,v.$$

But this cannot be integrated since $d\,p$ is variable, decreasing from A to B. But, for any assigned value of v, p is a function of τ only, and since $d\,\tau$ is constant from A to B, we express $d\,p$ as a function of τ. This, according to the calculus, may be expressed thus:

$$\frac{d\,p}{d\,\tau}\,d\,\tau$$

and our expression becomes

$$A\,B\,f\,e = d\,\tau \int_{v_1}^{v_2} \frac{d\,p}{d\,\tau}\,d\,v$$

where $d\,\tau$ is placed outside the integral, since it is constant. If $\frac{d\,p}{d\,\tau}$ contains τ, the integration may be performed, because τ is also constant from A to B, or from v_1 to v_2. To illustrate, the differential of the most general form of the equation for imperfect gases, already given in equation (6), is

$$\frac{d\,p}{d\,\tau} = \frac{R}{v} + \frac{a}{v^2\,\tau^2} + \frac{2a_2}{v^2\,\tau^3} + \text{etc.},$$

which contains τ, but since that and $d\,\tau$ are to be constant from A to B, the integral may be performed, giving

$$A\,b\,f\,e = d\,\tau \left[R \log \frac{v_2}{v_1} + \left(\frac{2\,a_1}{\tau^2} + \frac{4\,a_2}{\tau^3} + etc. \right) \left(\frac{1}{v_1} - \frac{1}{v_2} \right) \right].$$

Observing that the area of each strip equals that of $A\,b\,f\,e$, and that the number of strips is $\frac{\tau}{d\,\tau}$, we find the area

$$M A B N = \frac{\tau}{d\tau} d\tau \int_{v_1}^{v_2} \frac{dp}{d\tau} d v = \tau \int_{v_1}^{v_2} \frac{dp}{d\tau} d v,$$

which is an expression for the total heat absorbed during the isothermal expansion, and hence equals the total work done.

It remains to be determined whether Thomson's absolute scale can be measured by a thermometer constructed of actual materials.

This scale would be represented by a perfect gas-thermometer, for all the work done by a perfect gas expanding isothermally will be external. Thomson and Joule made a series of delicate experiments upon air, known as the experiments with a "porous plug," to determine if air could be considered as a perfect gas when used as a thermometer, and it was found that the errors resulting therefrom were not greater than the errors resulting from direct observation, so that τ may be considered as the absolute temperature measured with an air-thermometer, and a good mercurial-thermometer agrees sufficiently well with the air-thermometer to be used in ordinary practice.

In the light of this solution, it may be asked: Is it not the heat absorbed during expansion that is to be divided into equal parts? While it is certain that it is so divided, it is equally certain that it is not the heat to which Rankine referred, when he said: "Let unity of weight of the substance possessing the actual heat Q . . . Conceive Q to be divided, etc." It is not the source of heat, nor the heat absorbed that is, fundamentally, divided into equal parts; but the heat of the working substance. We are explicit on this point, because we find that such an eminent author as Prof. Cotterell appears to have fallen into an error on these points. We quote from page 111, of his work on *The Steam Engine*, as follows:

"Let us now imagine the temperature T_1 of the hot body, or source of heat, to be divided into n equal parts, and let us imagine a quantity of heat, Q, to flow from that body to a second body, the temperature of which is $T_1\left(1 - \frac{1}{n}\right)$, then our results show that a quantity, $\frac{Q}{n}$, of mechanical work is capable of being produced, and that, consequently, if such conversion be effected, the quantity $\frac{n-1}{n} Q$ will pass into the second body. Now, imagine

a third body, the temperature of which is $T_1\left(1-\frac{2}{n}\right)$, and let this heat pass from the second body to the third body; then the heat capable of being turned into work, is

$$\frac{n-1}{n}Q\cdot\frac{T_1}{n}\cdot\frac{1}{T_1\left(1-\frac{1}{n}\right)}=\frac{Q}{n}$$

as before. This process may be continued indefinitely, and we thus see that—*If the temperature of a source of heat be divided into any number of equal parts, then the effect of each of these parts, in causing work to be performed, is the same.*"

Here the temperature—not the actual heat—is imagined to be divided; also, the source of heat is divided, not the heat of the working substance; also, Q is the quantity of heat imagined to flow from the source, while in Rankine's analysis, Q is the actual heat of the working substance. It is not clear what the division of the source into equal parts has to do with this analysis. This quantity, Q, is independent of the amount in the source, and also of that in the working substance; and it is assumed that this amount flows from the source *to* the second body, but that only an amount $\frac{n-1}{n}Q$ flows *into* the second body. The conclusion is also unfortunate, at least in form, for it reads as if the equal temperatures caused work to be performed, instead of equal heats. This attempt to explain Rankine's second law is, to say the least, not a success. The assertion that equal quantities of heat will do equal quantities of work, is nothing more than the first law.

In the case of a perfect gas, Rankine's operation of the second law, may be thus: Let one pound of the substance possessing the actual heat Q be conceived to be divided into n equal parts. While the substance possesses the actual heat Q, let it expand against a resistance doing work while its heat is maintained at Q by a supply from an external source, and after it has expanded by enlarging the vessel an amount $v_2 - v_1$, *Fig. 2*, let it be brought back in any manner to its original state of volume v_1 and heat Q; its pressure will then also be the initial, or p_1. Now, let $\frac{1}{n}$th of Q be abstracted from the substance at the constant volume v_1, the

pressure will fall to $(1 - n)\,p_1$, after which let the substance be again expanded at the constant heat $\left(1 - \frac{1}{n}\right) Q$, the same amount, $v_2 - v_1$, as before. Repeat the operation, by expanding it, the same amount, as before, from v_1 to v_2, at the heat $\left(1 - \frac{2}{n}\right) Q$, and so on. Then will the difference between the works done during the successive expansions be equal. It is in this sense that "the effects of the equal parts in causing work to be performed are equal." The operation may be represented geometrically by dividing the space $v_1\,A\,B\,v_2$ into n strips by isothermal lines extending from $v_1\,A$ to $v_2\,B$. This divides the external work $v_1\,A\,B\,v_2$ into equal parts, and since, in a perfect gas all the work will be external, the division accomplishes the purpose sought. The actual heat absorbed, $M\,A\,B\,N$, will also be divided into the same number of equal parts by the same isothermals.

But when the fluid is imperfect, this process will not divide the external work into equal parts, and much less afford any measure of the internal work, for the internal work is a function of the volume as well as of the temperature, as shown by the equation preceding (6). To illustrate the case for imperfect fluids, conceive successive isothermals drawn as before starting on the ordinate $v_1\,A$, but extended to the right to the adiabatic $B\,N$, then will the successive strips between the adiabatics be equal. For the area $M\,A\,B\,N$ represents heat—not work—and it will be divided into successive equal increments of heat. As the heat falls in temperature, the strips become longer and narrower, their areas remaining constant. It is this complex operation that is involved in the expression, "the effects of the equal parts in causing work to be performed are equal." The operation is known as Carnot's cycle, and we are thus brought to Thomson's Prop. II, and Clausius's mode of analysis. This solution admits of but one mode of division of the actual heat Q; that of a division according to a thermometric scale from zero to Q, and is unquestionably the mode of division intended by the author. It is not a division of the substance in which each part would have the original temperature of the substance, but one in which the temperature of the entire substance is reduced by the abstraction of equal quantities of heat from the substance. The equal parts of heat do no work, but are

indices of the grade of the heat doing the work. All of the heat doing the work must be of the grade Q, but to find the work which the heat absorbed can do, we conceive it to be worked in a perfect reversible engine, first at the grade Q, next at the grade $Q - d\,Q$, third at the grade $Q - 2\,d\,Q$, and so on, as already described, in which neither the beginnings nor endings of the works are arbitrary, but are limited by one pair of adiabatics. The phrase, "causing work to be performed," is not even suggestive of the manner according to which the work is to be done. Carnot's cycle is fundamental. Although Rankine deduced it from an independent hypothesis, yet had his analysis conflicted with this principle, the hypothesis and not the principle would have suffered.

We have thus established definitely the essential, and, we believe, the correct, meaning contained in the paragraph quoted at the beginning of this article.

(*To be continued.*)

ALUMINIUM AND ITS ALLOYS; WITH EXPERIMENTAL INVESTIGATIONS.

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Should we assume the existence of a metal superior in valuable properties to iron, and predict its entrance into the arts as a far more useful servant to man, even the remote possibility of such an event would be an interesting subject for discussion.

When, however, we can with truth point to the presence of such a metal in immeasurable quantities, it is indeed remarkable that in this age of progress such a wonderful substance should be so generally regarded simply as a chemical curiosity—the result of an interesting experiment.

This universally distributed metal, though now disguised, excels iron in lightness, is nearly equal to it in strength, does not rust or corrode by acid vapors and, what is more striking, is the third in respect to abundance of the constituents of the earth's crust.

This metal for which the arts have long waited, is aluminium, or "silver made from clay."

* Graduation Theses, 1886.

Mountains and valleys everywhere contain aluminium as their chief treasure, and even our city pavements are really ore-beds of a metal far more valuable than iron.

Though aluminium has been isolated and its wonderful properties known for over half a century, its production has hardly emerged from the form of a large laboratory experiment, and it is now so costly that it is far from occupying its true place in the arts.

At the present time, however, strenuous efforts are being made to cheapen its manufacture; and it may be that we can see and almost stand upon the threshold of an age of aluminium.

Yet so great have been the difficulties attending its cheap production in the past, it is perhaps best to be not too sanguine of new processes or results, until they have had more than a theoretical or experimental demonstration.

The history of this metal, though it forms but a brief chapter, has not, so far as the writer is aware, been written, except in the very briefest way, and chiefly exists, at present, in diffused and disconnected statements of discoveries and claims for new methods of manufacture.

As all the processes in vogue depend on the use of expensive chemicals, any slight change in manipulating the steps of the process, or use of the by-products, may materially reduce the final cost. It is doubtless for this reason that the details of manufacture have been so scrupulously guarded.

HISTORY.

Lavoisier first suggested the existence of metallic bases of the earths and alkalies at the beginning of the present century, but he was unable to isolate them.

Twenty years later, Sir Humphry Davy succeeded in obtaining metallic sodium and potassium, but he labored in vain to isolate the base of alumina. The next twenty years were marked by the labors of Berzelius and Oersted, the latter of whom was able to replace the oxygen in the $Al_2 O_3$ by chlorine, and then tried to obtain metallic aluminium by making an amalgam with potassium. The metal he thus obtained somewhat resembled tin in appearance, and he thought he had at last discovered the long-sought base. Wöhler subsequently wishing to prepare this amalgam from very pure substances, found it impossible to do so, and could not arrive at Oersted's result.

While thus the work of Oersted was unsuccessful, it marked an epoch in the history of aluminium from the direction it gave to all future experiments. He was the first to use the chloride which is now regarded as almost indispensable, and upon the use of which, in some form, depend all the commercial processes of manufacture at the present time.

This use of the chloride suggested to Wöhler the practicability of directly employing the chloride and some reducing agent. As a result of his labors in this direction, he was able, in 1827, to isolate the metal in the form of a gray powder, which, from its comminuted state, possessed few of the characteristics of the solid metal, and was exceedingly variable in its properties. It was also frequently contaminated with potassium sodium and their chlorides.

He also obtained very small quantities of the metal by heating the chloride and potassium in a closed platinum-tube. The aluminium thus produced was very infusible, as it doubtless contained platinum. We read with interest, as a sequel to these preliminary labors, that he discovered minute metallic globules in the gray powder of aluminium in 1845, but it was more than ten years later before he could produce these globules even of the size of a pin's head.

The labors of Wöhler had, in the meanwhile, interested many men of science, and among these the name of H. Sainte-Claire Deville stands pre-eminent. By him, the properties of the metal were first clearly demonstrated.

While endeavoring to produce a chloride of aluminium by heating certain substances in a furnace or muffle, he discovered, at the end of the operation, some shining metallic globules adhering to its sides. Elated by this discovery, he at once devoted all his energies to produce the precious metal in larger amounts. He began his work by using a glass tube, about four mm. in diameter, in which were introduced 250 grammes of $Al_2 Cl_6$, free from iron; this was separated in one portion of the tube, which was then heated with the rest, while hydrogen was passed over the chloride.

The hydrogen and the volatilized chloride then passed together over metallic sodium previously inserted, and the chloride was reduced to the metal. Finding that the obstacle to commercial success was the price of sodium, costing 2,000 francs per kilogram, in 1855, he exerted himself towards cheapening its production,

and brought its price down to at least within the possibility of using it for his purposes.

Deville, at this time, was a professor in the École Normale, Paris, where much of his work was carried on. The French Academy soon became interested in the subject of aluminium, and appointed Deville one of a committee to prosecute more thoroughly the experimental investigations he had already begun. Napoleon III also aided him with a present of about $7,000, and he began his great work for which he is famous.

Dumas says: "In saying that Mr. Wöhler discovered the metal, it should be added that Deville made it of greater purity and first showed its qualities for industrial purposes."

In 1855, we see for the first time a bar of aluminium in the Palais de l'Industrie, and the following year, Dumas showed to the Academy the first kilogram produced. These were important events in the history of the metal, as, up to 1854, it was produced only in the form of a powder by Wöhler's method. The next year, a helmet was made of the metal for the King of Denmark, and shown by Dumas to the Academy. It was then stated that the manufacture of sodium had been so greatly cheapened that aluminium could be easily produced in large quantities at 100 francs per kilogram. But while Dumas greatly underestimated its cost, its price fell from 3,000 francs per kilogram, in 1857, to 300 francs in 1859.

In 1867, it again appears in the Palais de l'Industrie, and, eight years later, in various marketable forms, as castings, sheets, foil, wire and finished goods, polished, engraved and soldered.

Deville, soon after his methods were deemed successful, started a factory in connection with Debray and P. Morin, at the works of Rousseau frères. Their processes were subsequently improved under the direction of Morin, at Nanterre; and also improved methods were used by Merle & Usiglio, at Salindere, near Alais. Twelve years after the metal had appeared in the form of castings and finished goods, the Paris Exhibition of 1879, showed that its production had reached a maximum, at which it has since practically remained.

The French were the first to carry out Wöhler's method, or, rather Deville's modification, on a practical scale, and it is the only country in which the industry has really prospered. Extensive

experiments were, however, early made in Berlin by Prof. H. Rose, and by Gerhard, in England, tending to cheapen the metal. Later, I. Lothian Bell attempted to manufacture aluminium commercially at Newcastle-on-Tyne, but about 1874 he was obliged to close his works.

Wirtz & Co., in Germany, also tried in vain to make its production a success, but it has still been left to the French to make it successfully, into the forms demanded by commerce, at Salindere and Nanterre.

Within recent years, vigorous efforts have been made in this country and again in England, to compete with the French manufacturers. In this country, the Cowles Electric Smelting and Aluminium Company are at present erecting a large plant at Lockport, N. Y., to produce aluminium and its alloys from corundum by a process of electric smelting.

In England, the manufacture is carried on by the Webster Aluminium Crown Metal Company, which makes, besides the pure metal, a number of valuable alloys. This company recently (in 1883) made a very elaborate display of their finished products in London, before sending their exhibit to the Calcutta Exposition.

ORES OF ALUMINA.

Aluminium is the most widely distributed metal on earth. It is never found in the metallic state, but always combined with oxygen and in this form, Al_2O_3, is the basis of many of the commonest rocks and the chief constituent of most clays. It is found in porphyries, igneous rocks, and in connection with quartz in granite, gneiss, mica, schist, syenite and some sand-stones, while sapphire and ruby consist exclusively of it.

A very brief glance at the pages of any manual of geology shows that a very large per cent. of aluminium-bearing rocks contain over sixty per cent. of aluminium, while a large number contain over eighty and nearly ninety per cent. of the oxide. These minerals are widely distributed both in this country and Europe, but from reasons partly of a commercial nature, the deposits of French clay or bauxite, at Beaux, near Arles, France, the English and Irish clays and the cryolite from Evigtok (Greenland), and from

Norway, are the most familiar as aluminium-producing ores. By the methods of electric smelting, such refractory ores as emery and corundum can be used advantageously.

The utility of cryolite and bauxite was early discovered, and upon the use of one or both of these minerals, most of the early and many later methods depend. Wöhler employed cryolite and showed many of its properties, among which, perhaps, the most important is its lightness, enabling it to be used as a flux, which will float on the surface of the molten metal. This circumstance is of great importance, as will be seen, when we remember that the density of aluminium is only about two and one-half times that of water.

At the time of Wöhler's experiments, cryolite was imported to Germany as a "mineral soda," and was used for washing purposes.

While bauxite and cryolite have been held in about equal favor in the past, a recent experimenter informs the writer that bauxite possesses many advantages over cryolite.

Alumina appears in the kaolin deposits in Connecticut, New York, Virginia and Georgia, etc., etc., and is a large constituent of many common clays. The black clays, shales and slates, occurring with and between coal seams, frequently contain twenty to over thirty per cent. of Al_2O_3. Minerals containing seventy to eighty per cent Al_2O_3, are sometimes found with corundum or emery at Chester, Mass., Newlin and Unionville, Pa., Franklin, N. J., and Amity, N. Y.; while there is said to be a veritable mountain of sulphate of alumina in New Mexico.

VARIOUS METHODS OF PRODUCTION.

The following methods, or perhaps theories, for the production of aluminium are given with one that has proved itself to be of commercial value. The others are presented not wholly as being important in themselves, but as a guide to future experimenters.

In 1854, Deville employed a modification of Wöhler's method, by heating to a red heat a mixture composed of sodium and chloride of aluminium in a porcelain crucible. The excess of the chloride collecting together in a mass, in the centre of which was found globules of more or less pure metal.

He subsequently passed the vapor of Al_2Cl_6 over metallic sodium inclosed in a tube of iron or copper, and kept at a red

heat. As might now be supposed, the metal thus produced was very impure. Afterwards making it on a larger scale, he passed the vapor of the double chloride of Al and Na over metallic sodium, at the same time employing cryolite or fluorspar as a flux, the vapor being produced by heating the following ingredients together :

Chloride of Al and Na, ...	10 parts.
Fluorspar, or cryolite, ...	5 "
Sodium, ...	2 "

The double salt and the fluorspar, or cryolite, were pulverized and mixed together in proper proportions with the sodium also in small pieces. The whole mixture was then placed in a reverberatory-furnace that had first been raised to a red heat—the air being always excluded. A very violent chemical action at once takes place and great heat is evolved. When the reduction has proceeded sufficiently, the slag and then the metal is run out. By this method, with a furnace containing about sixteen square feet, about sixteen pounds of pure metal was produced.

Aluminium was prepared by Heinrich Rose, of Berlin, directly from cryolite, by mixing this mineral with half its weight of common salt, and arranging this mixture in a crucible with sodium in alternate layers, and in the proportion of sodium two parts and cryolite mixture five parts. A great advantage was claimed for this use of cryolite, because it obviated the use of the single or double chloride of aluminium, and was itself a natural product found in large quantities. One of the chief difficulties was that, as the crucibles were either of iron or clay, the metal was considerably contaminated with iron or silicon and from which it was impossible to free it.

But, however successful the work of Rose might have been, Deville, Rousseau and Morin concluded that it was best to prepare the chloride of aluminium and then decompose it by sodium.

The first industrial preparation of the pure metal was effected by distilling Al_2Cl_6 in a vertical retort, and passing the vapor through a cylinder containing fifty to sixty kilograms *de pointes de fer*, and heated to a low red heat. From this, the vaporized chloride passed into another cylinder containing 500 grams of metallic sodium placed in small dishes.

The Al_2Cl_6 produced in the first dish a double salt of Al and Na, which vaporized and passed with the excess of the chloride to

the next dish, where more of the double salt was similarly produced. The whole then passed on to the third dish of sodium, where it was reduced to the metal and chloride of sodium.

When this action was completed, fresh dishes of sodium were substituted. This process was afterwards modified by using at first the double instead of the single chloride.

When the utility of cryolite as a flux had been demonstrated, Deville, Debray and Morin employed the following proportions:

Double Chloride, ...	400 grams.
Salt, ...	200 "
Fluoride of Calcium, ...	200 "
Sodium, ...	75 "

in which the fluoride was replaced by cryolite. The double chloride and fluoride, or cryolite, were pulverized and mixed together and arranged in alternate layers with sodium in iron or earthen crucibles, which were first moderately heated and then the heat increased until the mass melted.

If the operation was successful, about twenty parts of the metal was obtained in a compact mass, while about five more were encrusted in the slag. The same difficulty occurred in this process as in the one already mentioned; the metal became alloyed with iron or silicon.

Several ingenious methods have been devised to avoid the use of the chloride, and in its place use alumina and its sulphate. The one to be described can be operated either in a crucible, or, on a larger scale, in the following furnace. This furnace properly consists of three shaft-furnaces, made of some refractory material, two of which can be closed by an iron cover or other contrivance. They communicate with each other by channels, which can be closed by slides. Two of the furnaces contain some fuel (as coke), and in these are provided steam and air-blast pipes; the latter making it possible to obtain a very high temperature. When in use, the middle furnace receives its charges in the following order: After the other two have been blown very hot, first a mixture composed of $Na_2CO_3 + C + S + Al_2O_3$ is inserted; then sulphate of alumina is added, and finally a flux, usually composed of the chlorides of sodium and potassium. The middle furnace is first made hot by burning some coke in it. The charge is placed immediately upon the coke, and as the latter burns away, the former

gradually sinks to the bottom. After this, it is generally necessary to mix coke with the charges. One of the heating-furnaces is now shut down, and steam is blown into and decomposed over the glowing coke; the oxygen liberated forming carbonic-oxide, and the hydrogen remaining uncombined. The gases thus produced pass, while highly heated to the central furnace containing the charge. The first result is to decompose it into sodium-sulphide and aluminium-sulphide, which are reduced together by the second charge (sulphate of alumina). The metallic sodium does not appear, as it at once performs the same office as in the chloride methods of reduction described.

The reduced aluminium can now be drawn off as it passes into the melting-zone of the furnace. When the reducing gases have become cooled, the other heating-furnace is operated in a similar way.

Instead of decomposing the charge into the bi-metallic sulphide of aluminium and sodium, pure aluminium-sulphide, or a mixture from which it can be produced, may be used; or pure sulphide of sodium, potassium or copper, or other metallic sulphide, producing the same effect on the sulphate of alumina. In the latter cases, however, the metal produced is alloyed with the metal of the sulphide.

The charge $Al_2O_3 + Na_2CO_3 + S +$ coal, may be changed to a mixture of Al_2O_3, S, and coal, only; and the process can be further simplified by employing one charge composed of sodium-sulphide and potassium-sulphide; the others being produced from Al_2O_3, or sulphate of Al_2O_3.

Different processes have been devised to cheapen the chloride methods of production, but it will be observed that they differ from the methods invented by Deville only in the merest technicalities of operation and description. One of these is to bring the fluoride or chloride of aluminium, volatilized in any way, into contact with nascent sodium, made by strongly heating the following mixture of—

62 parts,	Na_2CO_3
28 "	Coal.
10 "	Chalk.

or, in place of this mixture, any other may be used that will produce either sodium or potassium.

A method has been patented in this country by William Frishmuth, for extracting the metal from cryolite, corundum or bauxite, by first converting the materials into fluorides and then bringing them in immediate contact with sodium-vapor.

Equal parts by weight of the mineral and of fluorspar are dried together in a furnace, or crucible, at a bright red heat, to expel moisture. These materials are then pulverized, and to the mixture is added three-tenths ($\frac{3}{10}$) of its weight of fluoride of calcine. The mass is again heated and converted to a fluoride of aluminium and sodium. The double fluoride is then powdered and mixed with twenty per cent. of charcoal or some carbonaceous material, as oil. To each 100 pounds of this mixture is added twenty-five pounds of chloride of potassium, and ten pounds of chloride of sodium, the chlorides being first melted together. The whole mixture is now rolled into small balls, and thoroughly dried, after which they are placed in a retort with a perforated bottom. Through this bottom is conducted sodium vapor, made as follows, in another retort: Twenty parts by weight of calcined soda, ash or Na_2CO_3, ten parts of powdered charcoal, and five parts of chalk, lime or its carbonates. When these retorts are both highly heated, the sodium vapor produced, as above described, passes to the first retort, and reduces the metal from the fluorides.

This process can be changed somewhat, and instead of the fluoride of aluminium being first produced, the chloride is obtained. The required amount of the mineral is mixed with ten per cent. of fluoride of sodium or potassium, and sometimes an equal amount of fluorspar is added. After calcining, ten per cent. of carbonaceous matter, as oil or starch, is mixed with the mass, which is then rolled into balls and again dried. These balls are then placed in a furnace, through which a current of chlorine is passed, producing the aluminium chloride, which condenses in a separate vessel. In producing the fluoride from bauxite, it is likely to be contaminated with iron, and therefore it is preferable to decompose it with chlorine gas, the volatile chloride, which is made, being free from this impurity, and also others. The chloride may now be reduced in another retort, or it may be passed over metallic iron to free it from any iron chloride it may contain, and allowed to condense in another receiver. Metallic aluminium can now be obtained by passing the sodium vapor directly into this receiver.

These processes, in their general and principal features, are substantially the experimental methods at times used by Deville. In their present complicated form, they do not indicate a great commercial success.

Various interesting, ingenious, but at present unprofitable, methods for the reduction of alumina have been suggested, and depend partly on the use of hydrogen, and the formation of various aluminium alloys.

One of these was patented by W. P. Thompson, for the manufacture of Al, Na, etc. The operation was to be performed with an apparatus similar to the Bessemer converter, with either iron alone, or with hydrogen or carbon as the reducing agent.

After the iron was melted in one converter it was poured into the second, into which were forced streams of hydrogen or carburetted hydrogen, and chloride or fluoride of aluminium; the excess of hydrogen and ferric chloride being permitted to escape. At the end of this operation, an alloy containing a large amount of iron remains in the converter. This alloy is now transferred to the first chamber or converter, and the carbon is burnt out by a current of air. After being returned to the second converter, the reduction is continued until the iron is nearly burnt out, at which time hydrogen alone is to be used as the reducing agent. The iron, however, cannot be completely removed, and the final result is an alloy. When pure metal is to be made, sodium is used as a reducing agent, and into the chamber containing it the fluoride or chloride is allowed to enter.

The following hydrogen method was devised in England some years ago: Powdered fluoride of aluminium, either alone or with other fluorides, was heated in an air-tight furnace to a red heat, and at the same time was exposed to the action of hydrogen. Shallow trays of the fluoride were placed on the hearth of the furnace, preferably reverberatory, and surrounded by clean iron filings, in suitable dishes, to absorb the hydrofluoric acid produced on the admission of the hydrogen. The reduced metal was found at the close of the process at the bottom of the tray used for the fluoride.

The following attempt was made to obtain the metal by making an alloy of zinc. A series of steel retorts, 36 x 12 x 12 inches, having sides 7/8 inch thick, were used with the charge composed of—

Zinc ore,	100 parts.
Kaolin,	50 "
Carbon, anthracite coal, or its equivalent,	15 "
Chloride of Na,	10 "

The whole charge must be well mixed. The furnaces, which, it is said, must have a temperature of about 2,500° F., could be worked alternately, each receiving two charges in twenty-four to thirty hours.

ELECTRICAL METHODS OF REDUCTION.

Since the discovery of aluminium, efforts have been made at various intervals to reduce $Al_2 O_3$ by means of a current of electricity, and, as has been intimated, the work of the early experimenters has been in vain almost to the present time—as far as any practical results have come from their labors.

Deville and Bunsen used the battery in their investigations, and produced a very small amount of the metal electrolytically. The bath used was composed of two parts of chloride of aluminium and one part of salt. These ingredients were first pulverized together and then melted; the heat which was then evolved by their combination being sufficient to keep the solution very fluid. On passing a current from two Bunsen elements through the liquid, the metal was deposited on the platinum-pole in a fine powder. This was doubtless the furnace which Deville, while laboring under the patronage of Napoleon III, proposed to also use for purifying platinum, as the heat could be increased by increasing the current, until the impurities in the platinum were volatilized. After this first use of the electric-furnace, little progress has been made in the development of this mode of smelting until within very recent years. About six years ago, Sir William Siemens described a furnace designed to melt considerable amounts of such metals as platinum and iridium, whose fusion has always presented the greatest difficulties. His furnace, however, differed from Deville's, in that the electrodes were a carbon-rod and the metal to be fused, contained in a crucible made of graphite and surrounded outside by fine charcoal. An arc could thus be formed inside, and could be adjusted by suitable means.

The next year, Faure patented a furnace for the reduction of sodium and potassium; but although the plan appeared feasible, he did not put it in practical operation.

At the present time, there is a large factory in the course of

completion at Lockport, N. Y., and also in Germany, at Hamelingen, near Bremen, designed to produce aluminium, magnesium and kindred metals, by processes of electric smelting.

We have now followed very briefly the history of this mode of reduction; and as it is at present chiefly used in producing alloys of aluminium, we will leave its more detailed consideration to the chapter on aluminium-bronze.

FRENCH METHOD OF PRODUCING ALUMINIUM.

The process at present employed in various forms in France is, or rather has been, until within very recent years, the only one that has supplied the wants of commerce sufficiently to be regarded as an industry.

The following description of the methods in vogue at Salindere, is derived from a French authority of note.

The process differs from the one first used industrially, in that the double chloride of aluminium and sodium is substituted for the single chloride, Al_2Cl_6, though it is very hygroscopic, and, on becoming moistened, oxidizes to Al_2O_3.

The material chiefly employed at Salindere is bauxite, and the process consists briefly of the following steps:

(1.) Preparation of the aluminate of soda and the solution of this salt to separate the oxide of iron contained in the ore.

(2.) Preparation of $Al_2\,O_3$ by precipitating it from the soda solution with CO_2.

(3.) Preparation of the mixture of $Al_2\,O_3$, carbon and salt, and drying and treating with chlorine gas to obtain the double chloride.

(4.) Treatment of the double chloride with sodium to obtain metallic aluminium.

The aluminate of soda $Al_2\,O_3 \cdot 3\,(Na\,O)$ is produced by calcining a mixture of bauxite ($Al_2\,O_3$ and sesqui-oxide of iron), and carbonate of soda, and then dissolving and filtering off the soluble aluminate from the sesqui-oxide of iron. The alumina is now precipitated from the soda solution by CO_2, thus:

$$Al_2\,O_3 \cdot 3\,(Na_2\,O) + 3\,CO_2 + 3H_2\,O =$$
$$Al_2\,O_3 \cdot 3H_2\,O + 3\,(Na_2\,CO_3).$$

The formation of the double chloride by the action of chlorine on a mixture of alumina, carbon and salt, is thus expressed:

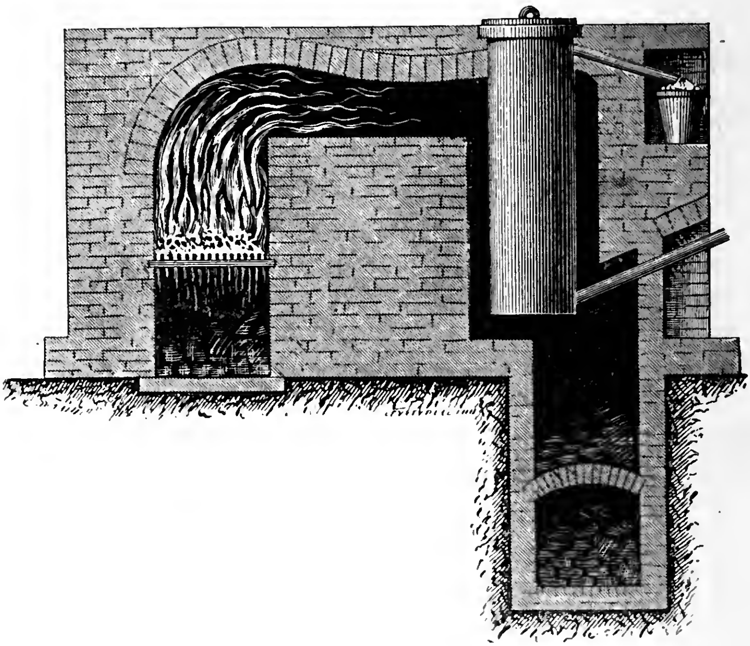
$$Al_2\,O_3 + 3\,C + 2\,Na\,Cl + 6\,Cl =$$
$$Al_2\,Cl_6 \cdot 2\,Na\,Cl + 3\,CO.$$

Finally, the reduction of the double chloride by sodium is:

$$Al_2\,Cl_6 \cdot 2\,Na\,Cl + 6\,Na = 2\,Al + 8\,Na\,Cl.$$

The two illustrations show the general feature of the furnaces used; and it is thought with sufficient clearness to need no particular description.

The first shows the furnace for the production of the double chloride. This operation takes place after the ingredients are



placed in the vertical cylinder and the gas led in from below. The chloride condenses in the vessel on the right.

The second illustration represents the furnace for the reduction of the double chloride; here cryolite is used as a flux to protect the surface of the molten metal.

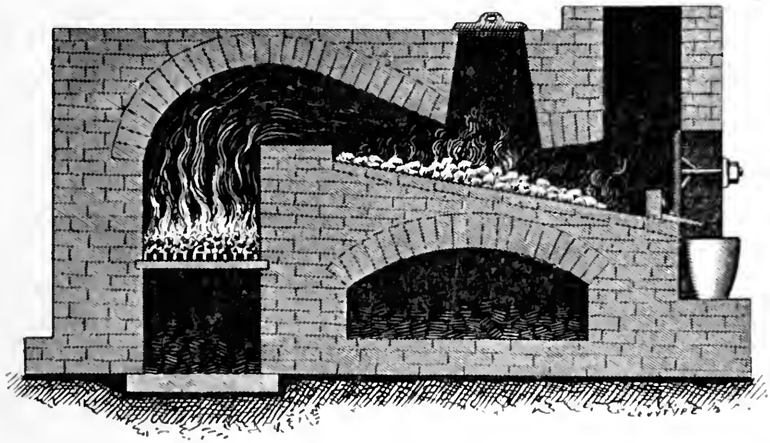
Considerable difficulty was at first experienced in aluminium manufacture to find a flux whose density was low enough and, at the same time, was free from iron.

Cryolite, however, seems to answer this purpose very well, and produces a very fusible slag beneath which the metal collects.

The proportions for the constituents of charge for the furnace shown is:

Double Chloride, ...	100 kilograms.
Cryolite, ...	45 "
Sodium, ...	35 "

The double chloride and cryolite are pulverized and mixed, and then divided into four equal parts. The sodium is divided into three parts, and is so put in that it has a layer of the double chloride and cryolite beneath it on the hearth of the furnace, and between it in successive layers, the top one being composed of the cryolite mixture.



As heat is applied, the first flow is melted slag, then aluminium, and finally a gray cinder, containing small portions of the metal.

PROPERTIES OF ALUMINIUM.

Aluminium is a silvery white metal, in many characteristics standing between zinc and tin. Its atomic weight is given by good authorities at 27·4 and 27·5, and density 2·5 to 2·67, when hammered. Its electrical conductivity was stated by Deville to be four times that of iron.

The following specific resistances of a wire, one metre long and one millimetre in diameter, are given in ohms as a result of Dr. Matthiessen's experiments:

Aluminium, ...	·03751
Iron, annealed, ...	·12510

Gold, annealed,	·02650
Silver, "	·01937

It is slightly magnetic and a very good conductor of heat. Its melting-point is somewhat higher than that of zinc, and it is said not to vaporize in the blast-furnace; though when boiling very rapidly, fine particles may be mechanically carried off from above its surface; on this fact is based one of the modes of separation already mentioned.

Its specific heat is variously stated at

·2143 Regnault,
·2020 Kopp,
·2183 Margottet.

When melted, oxygen readily unites with it producing Al_2, O_3, so that, in casting, it is necessary to keep the metal covered with charcoal or strongly-burnt cryolite, to absorb the oxide that may be formed, and at the same time protect the surface. It fills the moulds well, and when proper care is taken, makes good castings in moulds of iron or sand. If, however, it does absorb oxygen or becomes alloyed with traces of silicon, it becomes gray and brittle. For this reason, the crucibles used should be lined with carbon or calcined cryolite. The remarkable properties of the metal, in resisting corrosive agencies, are almost destroyed if it is contaminated during its manufacture or subsequent manipulation.

Aluminium can be easily polished and finished like silver in a solution of caustic potash. It is not attacked by sulphuretted hydrogen, ammoniac sulphide, or nitric acid, except at boiling temperature; nor is it acted upon by vegetable acids. Solutions of sulphates and nitrates do not injure it, and may be used for electro-plating solutions.

Hydrochloric acid is its true solvent.

The chief difficulty that has precluded its use has, of course, been its cost, and, next to this, a general ignorance of its properties and manner of working. It is, nevertheless, used for many optical and mathematical instruments, jewelry and fancy articles, where combined strength and lightness are desirable.

Many interesting speculations have been made as to the effect aluminium would have on commerce if it could take the place of iron—being nearly equal to soft iron in strength, and with a density of 2·6, while iron is about 7·2. It is easily seen that the

changes that would be produced in engineering, by the introduction of such a metal, would be unparalleled in the history of the world.

It has been proposed many times, in Europe, to use this remarkable metal for coinage, as it possesses two properties in the highest degree suited to this purpose—it is exceedingly light and is not easily tarnished. But the difficulty that will doubtless forever bar it from this use, is the difficulty of re-melting without loss from oxidation; for, it must be remembered, that when it has been again converted to alumina, it is of little more value than the ore from which it was brought, by a long and expensive operation.

The tensile strength of aluminium can be greatly increased by hammering it when cold, and its ductility admits of its being readily worked, under the hammer, into exceedingly thin sheets. The tenacity of cast-aluminium bars of one-ninth to one-sixth square inch section is given in the *Berg und Hüttenmänn Zeitung*, as 13,590 pounds, and the same cold-hammered as 25,120 pounds per square inch.

Seaton, in *Marine Engineering*, gives a tensile strength of eight tons per square inch, and states that after being treated, as above, the tenacity can be increased from seven tons (cast-metal) to about twelve tons per square inch.

METHODS OF SOLDERING ALUMINIUM.

The great difficulty of uniting two pieces of this metal by solder or flux, has been a very great drawback to its use even where the price was not a fatal objection. The trouble seems to be that when strongly heated for brazing a thin film of alumina is produced on the surface that effectually prevents a union of the solder and metal. This has also been found to occur with alloys of aluminium. However, by employing special care, pieces of the metal can be united by the following processes, some of which from the cost of the ingredients are impracticable on a large scale.

One of the early solders employed was composed of aluminium two parts, and silver one part. This ran with difficulty and formed a somewhat brittle union. The following mixtures, composed of tin and bismuth, have been used quite recently and it is said with success:

Tin, ...	85 to 95 per cent., by weight.
Bismuth, ...	15 " 5 " "

For a soft solder, the mixture becomes

Tin,	99 parts.
Bismuth,	1 part.

to which is added one part of Al when a harder solder is required. The proportions above given can be changed to—

90 parts of tin, and
10 " bismuth

for soft solder, and to

90 parts of tin.
5 " bismuth.
5 " aluminium

for a hard solder. The constituents are in any case to be melted together and cast into bars. The pieces to be united are first thoroughly cleaned and moderately heated, and the solder is then applied with an ordinary "copper," using vaseline or paraffine as a flux.

In 1859, when the difficulty of joining two pieces of the metal was becoming evident to experimenters, Mourey suggested the following, which was claimed to be perfect in its results. Five mixtures are given in order, the softest being placed first:

	Zinc.	*Aluminium.*
I,	80 parts.	20 parts.
II,	85 "	15 "
III,	88 "	12 "
IV,	92 "	8 "
V,	94 "	6 "

The proper proportion of the latter metal is first melted in a graphite crucible; the zinc is then put in slowly, while stirring constantly. Small pieces of fat or grease are placed on the molten solder to prevent the oxidation of the zinc, which would produce brittleness. After the surfaces to be united have been carefully prepared by first melting on them some solder, that, on the above table, is soft in reference to the one to be finally used, and afterwards carefully cleaning and smoothing, the articles are secured together and strongly heated over an alcohol flame. The hard solder is then applied with an "iron" of aluminium. To facilitate the flow and adhesion of the solder, a mixture of three parts copaiba balsam and one part of venetian turpentine, with a few drops of a vegetable acid, is used as a flux into which the solder is merely dipped. Care must be taken when heating not to oxidize the zinc.

There is quite an expensive method for uniting one of the alloys by solder, which we will notice hereafter.

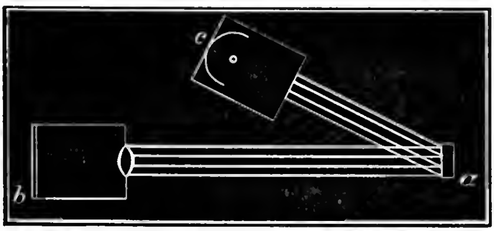
(*To be Continued.*)

HEAT-PHOTOGRAPHY.*

By F. E. Ives.

[*Read at the Stated Meeting, held Wednesday, February 16, 1887.*]

At the November meeting of this INSTITUTE, I described certain experiments in photographing by the aid of the phosphorescent-tablet, and announced the discovery of a means of photographing obscure objects by the action of heat-radiations. Since then, I have made several camera-photographs of metallic objects by the action of obscure heat-rays, which I placed the objects in a position to reflect. With a source of heat, produced with the consumption of coal-gas, at the rate of only three feet per hour, I obtained strong heat-photographs of small metallic objects, with camera-exposures of only ten seconds. But, although a moderate amount of heat was sufficient to give such striking results, it proved to be necessary, under ordinary conditions, to employ heat of a certain quality or intensity, which can be obtained only when the source of heat is also a source of light. My source of heat was the incandescent lime of the oxy-hydrogen light, placed in a dark box, one side of which was of black glass; the black glass transmits about thirty per cent. of the intense heat-rays, but no rays capable of producing phosphorescence, or of affecting bromide of silver. The arrangement is shown in this diagram:



a is the metallic object; *b* the camera; *c* the dark box containing the source of heat.

The object was focussed by the light-rays, allowance being

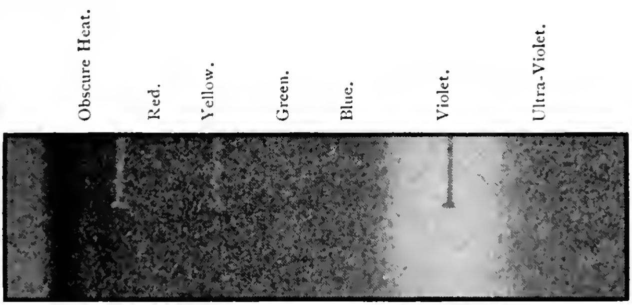
* This term may be objected to, but has been employed because the result of the method described is a fixed photograph of a fugitive thermographic impression.

made for difference of refrangibility of the heat-rays; the light was then extinguished by the black glass, and a solarized phosphorescent-tablet exposed in the camera. As I explained in my preliminary communication, this exposure produces a dark impression instead of the luminous impression that would be produced by violet light, and the photograph of this impression, made by contact-printing on a photographic sensitive-plate, is, therefore, a positive, instead of a negative.

I attempted to substitute a hot iron for the incandescent lime, as a source of heat, and even to photograph the hot iron itself, but without success. This might seem to indicate that the tablet is not sufficiently sensitive to the feebler heat-rays radiated by objects not heated to incandescence; but a simple experiment demonstrates that such is not the case. Contact with the hand for a single second will produce the characteristic sudden exaltation and partial exhaustion of phosphorescence in a tablet that has been kept at a sufficiently low temperature after solarization, and a simple calculation will show that enough heat is radiated from the hot iron to produce, in a little while, a strong impression in a camera some feet away. The knowledge of this and of the fact that rock-salt lenses transmit, and metallic mirrors reflect, these feebler heat-rays, led me to hope that I might photograph obscure objects without having to secure the special conditions that now appear to be necessary. My failure with the hot iron proved to be due to absorption of the heat-rays by aqueous vapor in the air. Prof. Tyndal found by experiment that the aqueous vapor in the air of his laboratory absorbed seventy times as much heat as the air itself. My experiments were conducted in very damp weather. and nearly all of the heat radiated by the hot iron was evidently exhausted in warming the air, and was carried away in air-currents. Although I did not accomplish what I hoped to in this direction, these experiments have made it evident that in a perfectly dry atmosphere, it would be possible to obtain photographs of obscure objects by the action of heat-rays of low intensity.

I have two illustrations of the method; one is a heat-photograph of a german-silver key-check, the other, a photograph of the impression produced on the solarized phosphorescent-tablet by the lime-light spectrum. The key-check photograph is quite small, but reasonably distinct. I believe it is the first heat-photograph

of an object that has ever been exhibited. The shadows of three pins are reproduced in the spectrum photograph; one was in the violet of the spectrum, another in the yellow, and the third at the lower limit of the visible spectrum. This photograph proves what I have already asserted,—that in Balmain's paint, phosphorescence is produced chiefly by the violet-rays, and the dark heat-rays below the visible spectrum act most powerfully to exhaust that phosphorescence. Exposures on the solar spectrum gave substantially the same result, but showed relatively more action by luminous heat, and distinct but very feeble action in a portion of the ultra-violet spectrum—the latter action was utterly insignificant as compared with the action of the same rays on bromide of silver.



Lime-Light Spectrum on Solarized Phosphorescent Tablet.

In my preliminary communication, I stated my belief that certain results that one M. Chas. Zenger recently claimed to have obtained by the aid of Balmain's phosphorescent paint could not have been obtained in the manner that he described. My later experiments confirm this belief, and I would not again refer to Zenger's communication had it not been widely published, attracting much attention. Balmain's paint is but feebly sensitive to invisible chemical-rays, glass lenses are practically opaque to all heat-rays radiated by bodies not heated above 200° F., and even a moist atmosphere will not transmit the feebler heat-rays to any considerable distance. If Zenger obtained a photograph of a midnight landscape in exactly the manner he described, it must have been by the action of light-rays that would have produced a much stronger and better photograph by acting directly upon the photographic sensitive-plate itself.

One other statement of M. Zenger's calls for correction by me.

He asserts that collodion-bromide emulsion-plates stained with chlorophyl are sensitive to all parts of the solar spectrum "from ultra-violet to ultra-red." More than seven years ago I discovered and published the fact that such plates are so remarkably sensitive to all colors as to be capable, with the aid of a weak yellow light filter, of producing correct-color-tone photographs of all colored objects; but it is not true that the sensitiveness extends to the ultra-red rays: it stops abruptly at the Fraunhofer line *a* in the red, as shown by spectrum photographs that have been made on such plates.

A WORD ON BASE-BALL-ISTICS.

By O. E. Michaelis, Captain of Ordnance, U.S.A.

AXIOMS.

(1.) The resistance of a medium to penetration increases with the velocity (rapidity) of penetration.

(2.) The angular velocity of a rotating body moving through a resisting medium is practically constant.

APPLICATION.

In *Fig. 1*, the ball is thrown in the direction *A B*, rotating to the left, as shown by the arrows. Evidently the hemisphere *A C B* rotates *with* the forward movement of the ball, and the hemisphere *B D A against* it. Therefore, the particles in the former are moving forward faster than those of the latter. Hence, by Ax. 1, the air opposes more resistance to the hemisphere *A C B* than it does to the hemisphere *A D B;* the ball accordingly follows the line of least resistance, and moves *inward*, as shown in *Fig. 2*.

When the "twisted" ball is delivered, its *initial* far exceeds its *angular* velocity. The first is rapidly reduced by the resistance of the air, the latter is not (Ax. 2); hence there must come a time when the angular equals, or possibly, exceeds, the initial velocity, then the ball will begin to "curve" rapidly.

CONCLUSIONS.

(I.) The trajectory of the rotating ball is always a line of double curvature—but the effect of the angular velocity at the beginning may be so slight as not to be perceived by the striker, who thus receives the impression that the delivery is "straight."

(II.) With a given twist (or angular velocity), a very "swift" ball would not "curve" enough; a very "slow" one, too much.

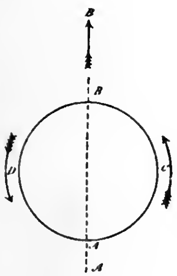


FIG. 1.
Centre of Inertia coincident with Centre of Figure.

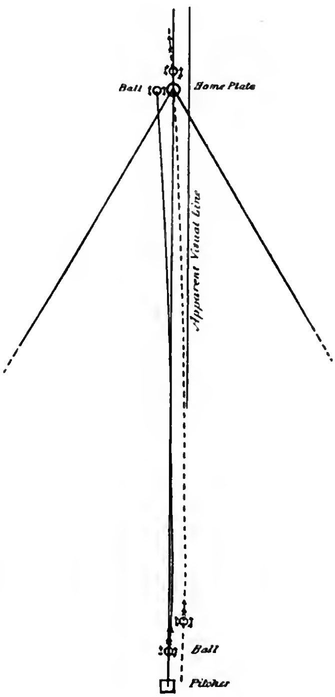


FIG. 2.

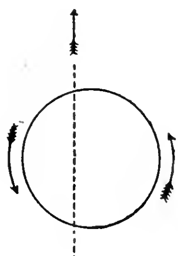


FIG. 3.
Centre of Inertia not coincident with Centre of Figure.

The "scientific" pitcher is he, who, knowing this from practical experience, selects the most appropriate "pace."

(III.) A ball always deviates *with* the twist, unless it rotates about the axis of projection, in which case the twist will produce no deviation.

The above is a *popular* explanation.

THE FLOW OF METALS IN THE DRAWING PROCESS.

ADDENDUM.

IN MR. OBERLIN SMITH'S LECTURE upon the "Flow of Metals," etc., upon page 23 of the JOURNAL for November, 1886, equation (5) should read $2\,(r' + r'') - 2\,c = r$ — instead of with the sign of equality after the first 2, as the printer made it to read.

To make clearer the derivation of equation (3), it may be said that therein the value x has been found for sharp cornered work, whose "contour" is, of course, its diameter plus twice its height. In equation (6) the value x is decreased by r — because its contour is that much less, by the amount $\frac{r}{2}$ — at each corner, as shown in equation (4). This assumes that there is no radial stretch in arc c, due to the "drawing" action. Practically this is nearly true for corners of small radius, but not for large ones, as explained in the previous paragraph.

BOOK NOTICES.

REPORT OF THE BOARD OF COMMISSIONERS OF THE GEOLOGICAL SURVEY OF PENNSYLVANIA TO THE LEGISLATURE, January 1, 1887.

This small pamphlet of six pages contains two small maps of the state, colored to represent the counties of which geological reports have been published, and the counties of which colored geological maps have been published. It gives a list of the work done in the field and by the printing-press during the last two years, and specifies fifteen odd jobs throughout the state which remain to be done. Among them, is "a detailed mineralogical survey" of the South Mountain, in Cumberland, York, Franklin and Adams Counties, "for which we have a perfect map basis." This map basis (doubtless Lehman's contoured map of the South Mountain) will prove a very important addition to the survey's records, but it was not known before this announcement that it was completed.

A "mineralogical survey" is one of those singularly unhappy expressions which, like human society in travail, 'voices a want for which itself cannot find words;' or, at least, the right ones. However interesting a mineralogical survey, or a search for minerals might be, a work more in keeping with the objects of the establishment and more important, would be the systematic study of the geological relations to each other of the several different formations represented in the mountain. It was for this purpose that the contoured map of the South Mountain was recommended and commenced under the direction of the former Assistant of the Southeast District of Pennsylvania. Why not allow his well-matured plan to reach fruition?

No proper effort has been made by the chief geologist to harmonize the conflicting views of the archæan and palæozoic geology of Chester, Delaware and Philadelphia, although they are parts of the geological column which are claiming the attention of geologists all over the world. It is a matter of speculation to what extent the "special local surveys in Chester and Delaware Counties" can conduce to this end. An appropriation of $90,000 is asked for the next two years. A great state like Pennsylvania should have a permanent geological bureau, economically administered, and charged with collecting, arranging and publishing the valuable information, which is lost in its absence every year. The head of such a bureau should be a man of large experience and industry, without prejudices that influence his work.

F.

THE STORY OF THE ROCKS. The Earth's Annular System. By Isaac N. Vail, with an introduction by Capt. R. Kelso Carter, Barnsville, O., Published by the author. 8vo, 375 pp. Appen. and Index.

It is a trait characteristic of most iconoclastic reform, that no matter what may be its subject, its apostles have a strong family resemblance, and argue (they would say reason) in the family dialect. We will suppose a being to have spent, say, thirty or forty years in the honest endeavor to fit himself for the understanding of the intricate and unsolved problems of geology. He has diligently searched out the best authors, and the best living teachers, and by the aid of both, and years of experience in the field, he is beginning to realize how little man can know of the great genetic problems connected with these studies, and to value the contributions to our knowledge made by the master minds devoted to them, though but a small part of the whole truth; when along comes a genius and tells him in the first line of his Preface that "the readers of this volume must first divest their minds as far as possible of pre-conceived opinions, however permanently time and education may have implanted them."

With this beginning, one braces oneself to hear a tremendous deliverance, which shall prove the necessity of "a thorough reorganization of the geologic record, as now interpreted." This turns out simply to be that the earth once possessed a ring, or system of rings, of aqueous vapor around its hot nucleus, and that the vapor was prevented from descending by the velocity of its rotation and by the heat of the central mass.

Most geologists, on reading this, will ask what it has to do with the "geologic record?"; and wherein consists its novelty? It has been held to be one of the probable transition states in the earth's genesis, ever since LaPlace (somewhat before Prof. Winchell) enunciated his "sublime conception," of which it is a corollary. As to the waters remaining suspended in the air for a considerable time after the earth was cool enough to hold them, very few could be found to take any other view: least of all that, that the waters descended all at once.

Amongst others, Dr. T. Sterry Hunt has very elaborately and graphically described this very condition of acid rains on the cooling earth, and perpetual clouds in the atmosphere, in his, "Some Points in Chemical Geology' (1857),

and "Chemistry of the Primeval Earth" (1867), (*Chemical and Geological Essays*, pp. 11 and 35), but it never occurred to him that he was revolutionizing the science. The idea that the fall of the water from the clouds caused the plications and upheavals of mountains, cannot be regarded as other than a forced and unlikely guess. It is scarcely worth while to say more of this book of Mr. Vail's, than that its main postulate is not new; its subsidiary deductions are not likely; and that the whole subject is of moderate importance compared to those parts of the history of the planet which relate to the gradual evolution of life.

It possesses a fictitious value by another effort to harness the poetry of the Hebrew Bible to the matter-of-fact deductions of modern science, and get out of the former more than its authors put into it. This attempt is also not new. It has baffled wiser men than Hugh Miller and Prof. Dana (the last chapter of whose *Manual* invites dreamers to continue in this unprofitable employment), and it is likely to continue to do so until it is abandoned like the ingenious word-puzzles of the schoolmen.

The idea that man's longevity was "impelled" by the suspension of aqueous vapor in antediluvian times (p. 95), so that he lived to 800 and 900 years, while his longevity diminished immediately after the "upper deep fell and the sun began to pour his beams upon the race," is somewhat startling; and, if true, must prove an entire change in the race since that time; for vital statistics show an increase in deaths (and especially in suicides) in cloudy weather. There could have been no rheumatism in antediluvian days.

Examples of the author's inaccurate logic are to be found widely distributed, such as the pressure of the atmosphere "unaffected by repelling heat," equalling so-and-so; "the equatorial belts of Saturn and Jupiter moving more rapidly than the polar, they must be moving independently of each other," etc.

Captain R. Kelso Carter also adds his quota to the non-sequiturs by stating as his sixth claim that "the falling of these rings to the earth somewhat weakened the cord of attraction for the moon, which therefore receded from the earth."

There are the usual defiances to science which attract only by their audacity in lieu of demonstration; the phrases and parts of phrases in italics, and the frequent recurrence of "it is evident;" "it stands proved;" "no one can deny;" "no sane man can for a moment doubt;" "we must draw the conclusion;" "tell me what else could have," etc.; "can we come to any other reasonable conclusion;" "the reader must see;" "there cannot be a man of reason who cannot see," etc.; "the annular theory declares to all the races of men under Heaven," etc.; "it must be admitted by every intelligent reader;" "it can readily be seen," etc. This is not the manner of a man who wishes to present a logical deduction of importance to his fellows. It was not thus that Aristotle, and Keppler, and Newton, and Bishop Butler and Darwin came before their fellow-men.

In short, the book is both pretentious and worse than useless. We hope for everybody's sake that the edition is small. F.

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS AND ASTRONOMY.

New Views Concerning Solar Spots and Faculæ.—Spörer (*Viertel-jahrschr. der Astron. Ges.*, **20,** Heft 4) calls in question the long-received theory of Wilson, according to which the spots have been considered funnel-shaped cavities, extending considerably below the solar surface. Wilson (1769) saw the complete disappearance of the penumbra on the side of a spot next the centre of the sun, when the spot was about to disappear at the western limb, or reappear at the eastern, and this asserted fore-shortening of the inner side of the penumbra he attributed to the great depth of the spot. Spörer insists that the facts gathered from many years of observation are not in accord with this theory. For, on the assumption of considerable depth, the outer penumbra should, as the spot is nearing the limb, be last visible. But actual observation shows first the disappearance of the inner penumbra, then also the outer penumbra, while there still remains the umbra, and north and south of it, penumbra. This phenomenon, as well as the disappearance of small spots of groups nearing the limb, is due to the fact that around spots lie areas of faculæ, over which rise hot currents of gas, and through which the spots near the edge must be viewed. Moreover, computations of parallax due to depression, are not reliable, since the effect of the refraction of the solar atmosphere and of the parallax results in displacement in the same direction. Regarding the average displacement in a ten-year series, as due alone to the solar atmosphere, the refractive index comes out 1·0021; regarding it as due to depression below the solar surface, the average depth is only 2″. Many series of observations show no depression whatever.

The solar faculæ are produced by hot currents from the interior of the sun, while the spots are currents directed from the cooler atmosphere toward the centre, and are seen projected on the surface of the sun. The downward-directed currents diverge below and contribute to the force of the outward-directed currents of hot gases.

Rev. F. Howlett (M. N. Royal Astron. Soc., **46,** 447), contributes very careful measurements of individual spots with symmetrical penumbræ, which are in entire accord with the view of Spörer. In one instance, he insists that the following, or inner side of the penumbra, was wider than the outer, when the spot was but 20″ from the western limb.

M. Faye (*Comptes Rendus*, T. **103,** No. 14), while in general accord with Spörer's theory of solar currents, draws attention to the lack of a sufficient cause for the downward-directed currents in Spörer's hypothesis, and believes that this cause resides in the inequality of velocity of horizontal currents, producing on the surface of the sun, as in our bodies of water, or in our atmosphere, descending gyratory movements. Under the impulse of such a force cold hydrogen, in the form of a cylindro-conic column, is made to penetrate the denser layers of the photosphere. M. B. S.

NEW VALUE OF "v."—F. Himstedt (*Wied. Ann.* **29,** 560) has lately made a careful determination of the important physical constant "v," the ratio of the electro-magnetic and electro-static units of electricity. In the older determinations, differences amounting to as much as four per cent. appear, while the newest determinations of Exner, $29{,}20 \cdot 10^9$, Klemencic, $30{,}18 \cdot 10^9$ and J. J. Thomson $29{,}63 \cdot 10^9$ are not very much more in accord. Not only do Himstedt's five sets of values agree well with each other, but his final value for $v = 30{,}074 \cdot 10^9$ cm/sec agrees well with a very recent determination by Klemencic, $v = 30{,}15 \cdot 10^9$. The observer proposes investigating the question, whether errors of former investigations are due chiefly to the electro-magnetic or to the electro-static measurements involved. M. B. S.

THE LIGHT-RATIO OF STELLAR MAGNITUDES.—S.C. Chandler, Jr., (*Astron. Nachr.* **115,** 146,) in a general discussion of the light-ratio between successive stellar magnitudes, used for magnitudes less than the sixth, the results of Seidel, Zöllner, Peirce, Wolf, Pickering and Pritchard, for comparison with the scales of the *Uranometria Nova* and the *Durchmusterung*, and concludes first that an inspection of results is forcibly impressive of the imperfect condition of instrumental photometry; secondly, that between the second and the sixth magnitudes the universally adopted scale is practically as iso-photometrical as could have been established by the most elaborate instrumental means; third, that the value of log. ρ here resulting is 0·350. From a discussion of telescopic magnitudes, he also finds the mean between the scales of Ceraski and Rosen to be 0·365. The author hence concludes that the evidence points to a uniform light-ratio in the neighborhood of 0·360. This makes the base itself 2·29 as distinguished from the old value 2·51.

M. B. S.

THE ATMOSPHERIC LINES.—M. Cornu (*Phil. Mag.*, **22,** No. 138,) has devised and carried into effect an elegant and successful method of distinguishing between spectral lines of solar and terrestrial origin. This method is founded on the principle of the displacement of the spectral lines of a source of light in absolute or relative motion. Applied to the light emitted by the solar disc at the two extremities of an equatorial diameter, and taking the velocity of a point on the solar equator as two kilometres per second, the velocity of light as 300,000 kilometres per second, we shall have a variation of wave length equal to

$$\Delta\lambda = \pm \lambda \times \frac{2}{300{,}000} = \pm \frac{\lambda}{150{,}000}$$

$+$ or $-$ according as the radiation is taken from the eastern or western end of the solar equator. The double displacement is, therefore, readily shown to be $\frac{1}{62 \cdot 4}$ of the distance between the two D lines, for that region of the spectrum. Small as the total displacement is, it may become sensible with a Rowland grating for almost all points of the solar contour; even for those far from the maximum separation.

The experimental method consists in alternately throwing upon the slit of the spectroscope the images of the two opposite extremities of the solar equator. This is effected by oscillating a condensing lens, which forms in

the plane of the slit a sharp image of the solar disc. Now one edge, now the other, forms the spectrum, and solar lines are distinguished from telluric at a glance; the former being relative to any fixed point on the cross wires displaced, while the latter remain stationary. M. Cornu gives a special study of the telluric bands α, B and A.

Prof. E. C. Pickering (*Science*, January 7, 1887,) had also suggested to Prof. Rowland the feasibility of photographing the spectra of opposite limbs, the image of the sun being formed on the slit by a double image prism, a method that seems to possess several advantages. M. B. S.

MOTION GIVEN TO THE AIR BY THE WING OF A BIRD. (*Comptes Rendus*, **103**. 1886.)—Observation has shown that certain birds can rise without preliminary impulse, with the axis of the body nearly vertical, and consequently giving their wings a nearly horizontal motion. The wing must then produce at this initial instant of flight a violent current of descending air, the reaction of which coming up from below will raise the bird's body. It is known, moreover, that if a bird's wing or fan is vibrated in the air, the air escapes lengthwise of the surface striking it. M. Müller attributes this effect to the fact, that a stratum of air is compressed against the surface of the moving wing, flows rapidly in the direction of the flexible edge of the wing, and carries after it a certain mass of air, communicating to it its velocity. The principle would be like that employed for ventilation, when air is carried in a long conduit, by injecting a jet of air with great force into it. Experiment has shown that under these conditions, in the same section of the injector-tube, the suction is stronger if the jet is spread in a thin sheet than if it is of a cylindrical form. The explanation of this is that in the first case the surface for friction is more extended. It has also been noted that the suction of the air is more intense when the injection is intermitted than when it is continuous. Now these two conditions, flattening of the stratum of air in motion and intermittance of the jet, are combined in the movement of the air, which flows at a tangent to the plane of a bird's wing. Finally, if a thin layer of air escapes from the back-edge of the wing, and parallel to the plane of it, a reaction also parallel to this plane will be produced along the front-edge, where the bony portions in relief prevent the air from escaping; it is this reaction, which makes the bird advance. To demonstrate the reality of these phenomena, M. Müller has arranged little contrivances, by which the loosening of a spring gave to a wing or a flexible plane, a fluttering on a small scale. He then studied the movements, which were produced in the air (by making this visible) in daylight by means of smoke, following Tyndall's example, or at night by phosphorescent vapors. The existence of the compressed sheet of air, escaping along the thin edge of the wing, was revealed to him by the following experiment. In front of this flexible edge, a thread of cotton is burned, which sends up a thin, vertical column of smoke into the quiet air. The plane is lowered, a transparent aperture is produced in the column of smoke by the layer of air which escapes under the wing; this stratum draws after it, at right angles with its original direction, the column of smoke, which continues to form under it. The layer of air which escapes,

following the plane of the wing, is scarcely ten millimetres or fifteen millimetres thick; the faster the motion moreover, the thicker the air is. This current, on penetrating the motionless air, encounters resistance and produces whirls, which increase in size, in proportion to the distance from their source, the edge of the wing; they attained in the experience of the author a decimetre in diameter. These whirls, which form one after another on both sides of the current of air, have an opposite rotation on the two sides. To render them visible, the author let the smoke or phosphorescent vapors accumulate under the wing, which he suddenly lowered, seeing then the two series of whirls form, grow and multiply, speeding-off and turning in opposite directions on the two sides of a plane in continuation of the wing surface. Finally, to show that a projection on the edge of the moving plane holds back the air and prevents its escape, he made use of a simple fan of folded paper, and after having proved that a certain rapidity of fanning produces a draught, he edged the fan with a narrow band of paper at right angles with its surface. By influence of this slight projection, which holds back the air, the breeze is stopped. To recall it, more rapid movement must be given to the fan; the layer of compressed air is then increased in volume and escapes over the barrier. C.

Electric Conductibility of Gases and Vapors.—Many theories relative to electrical machines and atmospheric electricity are still founded upon the supposition that damp air is a conductor, or that gases and vapors can become electrified by friction, although it has repeatedly been proved that they are very poor conductors. M. Jean Luvini, from the results of his experiments and those of other investigators, has arrived at the conclusion that gases and vapors under any pressure whatever and at all temperatures are perfect insulators, and that they cannot be electrified by friction either among themselves or with solid bodies or liquids. M. Luvini applied his tests to air saturated with steam at different temperatures from 16° to 100° C.; hydrogen and carbonic acid not dried, but in the state in which they come from the bath which produces them; air heated by live coals or by candle flame, smoke from an extinguished candle, fumes of sugar, chamomile, incense, mercurial vapor at 100° C., the fumes of sal-ammoniac, etc. In no case was there the least evidence of conductibility. It is generally believed that gases greatly rarefied, or at very high temperatures, are conductors. This error arises from confounding the resistance to disruptive discharge with the resistance to conductive discharge. Masson found that with equal potential the distance of disruptive discharge is twelve or thirteen times greater in air than in water. Thus, the resistance of water to disruptive discharge is greater than that of air; but who would conclude from this that air is a better conductor than water? C.

MECHANICS.

The Results of a Mathematical Investigation of the Limitations of the Expansion of Steam, by Prof. William Dennis Marks, of the University of Pennsylvania, can be epitomized as follows:

We cannot expect, under the most favorable circumstances, to reach an economy which will surpass but very slightly one pound of coal per indicated horse-power per hour.

This would place eighteen per cent. of the heat in coal as the extreme limit of its utilization. The condensation of steam occurs during its admission to the cylinder, and in some cases is surprisingly great.

The law of this condensation is as follows:

The condensation of the steam in the cylinder is proportional to—

(1.) The difference of temperatures of the steam at the point of cut-off. and while being exhausted.

(2.) To the area of cast iron exposed to the entering steam up to the point of cut-off.

(3.) To the time of exposure of the interior surface of the steam cylinder to the exhaust steam.

(4.) The condensation is reduced by compression, subject to the same laws, but this is usually quite a small quantity.

The initial condensation of steam is due principally to the piston and cylinder heads.

The equilateral hyperbola approximates quite as closely as any other curve to the curve of expansion of steam in engines not embarrassed by a sluggish valve motion.

Compression will save some vaporous steam, but will not largely diminish the initial condensation because of its short duration.

Superheating is the most efficient expedient for economizing coal.

The steam jacket is not so efficient as is ordinarily assumed.

Slide valves are frequently the cause of large and unlocated losses.

The valves and pistons of steam engines are rarely steam-tight.

With properly designed compounded cylinders, the ultimate expansion of the steam is a function of the ratio of the two cylinders.

The saving in compound engines is due to lesser initial condensation in the non-condensing cylinder.

From the physical properties of iron arises the necessity of, and advantage of, compound engines.

The beneficial effects of superheating, steam-jacketing and compounding, are more apparent in small than large engines.

The most economic ratio of stroke to diameter for steam cylinders is a function of the number of expansions, of the boiler pressure, of the exhaust pressure, and of the number of strokes per minute.

A large cylinder is more economical than an equal volume divided among small cylinders.

High rotative speeds demand shorter cylinders than are ordinarily used.

It is frequently, especially with high boiler pressures, the more economical to not use a condenser.

The throttling of steam, with an engine of fixed expansion and small cylinder, does not increase the consumption of coal per indicated horse-power per hour, but very slightly. W. D. M.

CHEMISTRY.

ON THE CARBONIC ACID CONTENT OF THE ATMOSPHERIC AIR. By R. Blochmann (*Ann.* **237**, 39-90).—The above paper combines a thorough comparative study of the methods employed and the experiments performed up to the present time, for the purpose of determining the amount of carbonic acid contained in the air, with an account of the modification and improvement by the author of the Dalton-Pettenkofer method for determining atmospheric carbonic acid. Considerable space is devoted to the discussion of the sources of error, to which the various methods heretofore employed are subject, and attention is called to the fact that as more refined methods came into use, and more care was taken to determine and eliminate errors of experiment, the smaller the accepted figure for the amount of CO_2 in the air became. Thus:

PERIODS.	NUMBER OF—		Vol. CO_2 in 10,000 Vol. Air.
	Observers.	Observations.	
1828 to 1830	1 (Saussure)	201	4·1
1830 " 1856	6	322	3·6
1856 " 1885	22	> 4,000	3·1

Of all the methods hitherto used for determining the carbon dioxide of the air, the so-called Pettenkofer method, on account of its simplicity and rapidity, was chosen by the author as the one whose imperfections could be dealt with with the greatest hope of success. The principle of the method is this, viz., into a large glass bottle containing the air to be examined, is run a measured quantity of standard baryta water. The bottle is then corked and shaken, and the baryta solution transferred to a suitable vessel, titrated with standard acid, and the excess determined. The principal sources of error are, first, the absorption of CO_2 by the baryta solution from the air of the room during the titration. Second, in washing the bottle with hot water, more or less decomposition of the glass occurs, rendering the solution more alkaline. Third, in the use of caoutchouc stoppers, which, in accordance with numerous observations, when in contact with alkaline liquids, undergo oxidation, with the liberation of carbon dioxide. The first of these difficulties has been met by the employment of a compound burette, communication between the two halves of which is effected by means of a three-way glass stop-cock. In this piece of apparatus, both the acid and the baryta solution to be determined, may be measured and titrated out of contact with the air, with the greatest accuracy. The second of the above operations has been rendered unnecessary. In order to avoid the use of caoutchouc, the neck of the bottle is fitted with a stopper, consisting of a well-fitting glass-plate, a layer of mercury, and then a layer of paraffin, the whole being bound down by a piece of sheet-rubber. Through the stopper pass two glass-tubes with stout walls, and supplied with glass stop-cocks. One of the tubes reaches to the bottom of the bottle.

The sum of the constant errors affecting any result by this method is ·10 and the probable error of a single experiment lies between + 0·025. The following table contains estimations of the carbon dioxide in the air from the laboratory garden, Königsberg:

Dates.	Bottle No. 64. Vol. CO_2 in 10 000 Vol. Air.			Bottle No. 95. Vol. CO_2 in 10,000 Vol. Air.			Joint Mean.
	I	II	Mean.	I	II	Mean.	
1885, September 4	3·09	3·11	3·10	3·06	3·11	3·08	3·09
" " 5	3·24	3·24	3·24	3·25	3·26	3·25	3·25
" " 6	3·10	3·13	3·11	3·11	3·11	3·11	3·11
" " 7	3·09	3·08	3·08	3·07	3·09	3·08	3·08
" " 8	3·19	3·15	3·17	3·19	3·18	3·18	3·18
" " 9	3·15	3·18	3·17	3·15	3·17	3·16	3·16
" " 10	2·95	3·00	2·97	2·98	2·98	2·98	2·98
" " 11	2·91	2·96	2·93	2·94	2·95	2·95	2·94
" " 12	3·16	3·13	3·14	3·14	3·15	3·15	3·15
" " 13	3·06	3·09	3·07	3·03	3·05	3·05	3·06
		3·10				3·10	3·10

A. G. P.

A New Reaction for the Detection of Small Quantities of Hydrocyanic Acid.—G. Vortmann (*Monatschefte*, **7**, 416,) states that Playfair's reaction of the cyanides and nitrites is an exceedingly delicate test for a cyanide or hydrocyanic acid, the resulting nitro-prusside being recognized by its reaction with sulphides. The liquid to be tested is mixed with a few drops of potassium nitrate solution, from two to four drops of ferric chloride solution, and enough dilute sulphuric acid to change to bright yellow the first formed yellow-brown color of the basic iron salt. The mixture is heated until it begins to boil, then allowed to cool, and after the separation of the excess of iron a few drops of ammonia are added; the liquid is filtered and the filtrate treated with one or two drops of a much-diluted solution of colorless ammonium sulphide. The presence of hydrocyanic acid in the liquid will now occasion a beautiful violet color, changing in a few minutes to blue, then to green and yellow. Traces of hydrocyanic acid occasion only a bluish-green color, that rapidly becomes yellowish. The limit of the reaction is put at a dilution of 1 : 312,500, ten cubic centimetres of liquid being used; the limit of the Prussian blue reaction is 1 : 50,000; that of the ammonium rhodanate 1 : 4,000,000. W. H. G.

A New Explosive Mixture.—A. Cavazzi (*Gazzetta Chimica Italiana*), in studying the reduction of potassium nitrate by various substances, has found that a mixture of equal parts of the nitrate and sodium hypophosphite detonates violently when heated to about the fusing point of the mixture. The experiment should be made on small quantities only, and while other proportions yield an explosive mixture, those mentioned are the best.

W. H. G.

Determination of Fat in Milk, etc. M. Kretzschmar. (*Chem. Zeitung.* 1886. 100.)—A gravimetric determination of fat in milk and other

emulsions is generally done by evaporating to dryness a weighed or measured quantity of substance in a porcelain or platinum dish, in which beforehand a layer of powdered gypsum is placed, sufficient to absorb all liquid. The dried mass is then removed from the dish by means of a suitable instrument, powdered and extracted. In a laboratory, where a large number of fat determinations are to be made, the removal of this cement like adhesive residue from off the porcelain or platinum dish, is a troublesome and time-taking operation. This difficulty of the evaporation method is obviated by the following modification: By means of a suitable ball of cotton, or similar material, a piece of tin-foil is firmly pressed into the dish so as to form a close-fitted lining. A proper quantity of powdered gypsum is then placed into the dish, and a cavity made for the reception of the milk, etc., which, after absorption by the gypsum, is evaporated without stirring. (The use of sand instead of gypsum is not admissible, as it furnishes too low results.) After evaporation the whole contents are easily removed from the dish with the tin-foil, and after cutting the latter into shreds, powdered to be, lege artis, extracted.

Hoffmeister's thin glass dishes would, perhaps, be handier, but much more expensive than this very expedient tin-foil lining. L.

TREATMENT OF THOMAS-SLAG FOR FERTILIZING PURPOSES. L. Blum. (*Chemiker Zeitung.* 1886. 100.)—The first experiments in applying crude Thomas-slag directly as a fertilizer having turned out satisfactorily, any chemical treatment rendering the phosphoric-acid soluble, being unnecessary, the author proposes—in order to obviate the grinding of the slag—to subject it in the molten state to a jet of steam of from two to four atmospheres pressure while it is discharged from the converter, quite similar to the preparation of slag-wool. As Thomas-slag always contains a large excess of lime, in this case, however, no slag-wool is obtained, but a fine, fibrous powder requiring no further treatment. By the chemical action of steam upon the molten slag, metallic granules are oxidized, and the sulphur of the slag is partly eliminated. L.

NOTES ON RUSSIAN PETROLEUM.—(*Continued.*)—See this JOURNAL **123**, 76.—Three forms of stills are in use in the refineries of the Baku district, viz.: the upright cylindrical still of wrought iron, the so-called wagon-body still, and the horizontal cylindrical still. The last of these forms is almost exclusively used in the larger refineries. A large number of these horizontal cylindrical stills are generally placed side by side, and so are fed with crude naphtha from a common pipe, which runs along in front of the row, with short vertical branches delivering the oil into each still. The hot-oil residues are taken off from the lowest part of the still by wide pipes, which connect with a common horizontally placed pipe. And, as by the breaking of these pipes, filled with highly-heated residual-oils, dangerous fires could readily ensue, which would make it impossible to get to the connections of these pipes with the stills to close the valves from the outside, the valves are placed *inside* the still, while the valve stems reach through the still and project above, where they are easily accessible. In the Nobel refinery, an open trench, through which water is kept continuously running, is laid along before

the row of stills, so that all dripping oil is carried away at once, and the ground and space near the stills does not become saturated with oil—a most fruitful source of danger.

Quite frequently, *dephlegmators*, or so-called "separators," are interposed between the helmet of the still and the condenser, so that the vapors of the burning-oil distillate are separated from the lubricating-oils mechanically drawn over with them. These condensed, heavier vapors either flow back by a separate connection into the still, or into a distinct receptacle, and afterwards serve for the manufacture of what is called "solar-oil," a grade of illuminating-oil. One of the characteristic features of the Baku petroleum distilling is the almost exclusive use made of "astatki," or oil-residue, for fuel. The great scarcity of wood or coal in that country caused both crude-oil and its distillation products to be used for fuel from the beginning of the operations there. Prof. Engler states that the heating value of these residues is almost double that of bituminous coal, and that ordinary burners using this "astatki" can evaporate twelve times the weight of water compared to that of fuel used, while the best burners, with one kilo of "astatki," can evaporate fourteen to fifteen kilos of water. Three to four parts by weight of these residual-oils used as fuel will suffice to carry on the distillation of 100 parts of crude-oil for the burning-oil fraction.

The burner in which these residues are used, or "forsunka," as it is called, locally, has various forms. The essential feature in all the forms is the atomizing of the oil by super-heated steam, and the burning of it in this condition. The temperatures attained are, in some cases, so high that wrought-iron is fused thereby, so that the bottoms of stills, heat-pipes, etc., must be protected from immediate contact with the flame of the "forsunka."

Of course, this "astatki" serves as the material for the manufacture of lubricating-oils, but the amounts obtained are so large that the greater part is still used for fuel, so that not only is all distilling done with the aid of it, but it is used throughout the entire district for steam-generating both for stationary-engines and for ships and locomotives. Thus, the steamships of the Caspian Sea, and, in part, those of the Black Sea and of the river Volga, the locomotives of the Trans-Caucasian, the Trans-Caspian, and other Russian railroads, make use of this "astatki" as fuel.

Although the results vary somewhat, the percentages of the several products may be given as follows:

	Boiling Point.	*Per Cent.*
Benzine (with gasoline),	— to 150° C.	5 to 7
Kerosine I (burning-oil),	150° to 270° C.	27 to 33
Kerosine II (solar-oil),	270° to 300° C.	5 to 8
Residues,	300° to —	50 to 60

These residues, which make up one-half or more of the total crude-oil distilled, show a sp. gr. of 0·900 to 0·910, and, although, as compared with American petroleum residues, they show extremely small amounts of paraffine, they yield on distillation a considerable amount of oils, which, on account of their viscosity, their low cold-test and high fire-test, are among the best

mineral lubricants known. The manufacture of lubricating-oils is, however, just beginning to develop. Taking the production of crude-oil in 1885, at 16·4 million metric centners (11·714286 barrels), and assuming the production of fifty-six per cent. of residues, we would have 9·2 million metric centners (6·571428 barrels) residues. If 1,000,000 metric centners of this be allowed for the needs of the refineries for fuel, steam-generating, etc., we still have 8·2 million metric centners (5·857143 barrels), for the lubricating-oil manufacture. This yields on an average forty per cent. of lubricating-oil, which would amount, therefore, to over 3,000,000 metric centners (2·142857 barrels). But the lubricating-oil production of Baku and the surrounding district, does not yet amount to the tenth of this, being in 1885 only 260,000 metric centners (185,714 barrels.)

The amount of residues needed for fuel in the distillation of lubricating-oils, amounts to twenty per cent. of the charge, instead of the three or four per cent. mentioned before as necessary for the burning-oil distillation.

In connection with the transport and the marketing of the oil, the Nobel Brothers, as said before, have been the most active. They had, in 1884, for use on the Caspian Sea and the Volga, a flotilla of sixty-nine ships, one-third of the number being steamers, and for railroad traffic about 2,000 tank-cars. They had, moreover, extensive storage tanks at all prominent points in Southern Russia, and even as far North as St. Petersburg and Riga. Some 900 tank-cars are also in use on the line of road between Baku and Batoum, on the Black Sea, and a pipe-line for this distance is projected.

Tank-steamers for the transport of Russian-oil in bulk between St. Petersburg and Stettin and Lübeck, in Germany, are now building. S. P. S.

HEATING AND SMELTING EXPERIMENTS WITH WATER-GAS.—H. Rösler and M. Ehrlich publish very interesting results on this subject in the *Sprechsaal*, 1886, p. 747, and reported in *Dingler's Polytech. Journal*, **263**, 108. The experiments in question were made at the parting and refining works at Frankfort-on-the-Main. It was found that water-gas made in a Wilson generator, and averaging in volumes: eighteen carbon-monoxide, ten hydrogen, sixty-eight nitrogen, four carbon-dioxide, was quite serviceable for boiler-heating, but unfit for smelting purposes. The melting temperature of silver could hardly be reached, the gas having lost its generating temperature of 400° C. by the transit from the generator to the furnace. By utilizing this temperature and heating the air of combustion, the ordinary smelting operations could be performed; but, nevertheless, the use of this Wilson generator was discontinued, because the gas was not cheaper than other fuel for boiler-heating.

Since 1885, the refining works use water-gas furnished by the neighboring Frankfort gas-works, at the rate of six pfennige per cubic meter, or 39·1 cents per 1,000 cubic feet. This gas averages: thirty-six carbon-monoxide, fifty-one hydrogen, seven nitrogen, four carbon-dioxide. It is not stated by what process this gas is manufactured. In composition, it is identical with the Lowe gas. This gas is still too expensive for all crude purposes; it is, therefore, only used in melting gold, silver and their alloys; fluxes and pigments for the decoration of china, and all purely laboratory work.

This water-gas was compared with the rich illuminating-gas of the Frankfort gas-works, and the leaner gas of the English company at the same city. The burners used were identical.

(1.) A copper vessel, filled with water, was heated from 15° to 100° C., under identical conditions. It took ten cubic metres of water-gas against four cubic metres of Frankfort rich gas, and five cubic metres of the English company's gas.

(2.) Equal weights of two kinds of flux for enamelling colors were melted under identical conditions, in a Perot furnace. The cost of the gas in each operation was M. 4·60 and M. 6·50 for water-gas, against M. 19·6 and M. 26·8 for the rich Frankfort gas.

(3.) Equal quantities of fine silver and copper were melted with the two gases in the same furnace. It required of water-gas M. 4·30 and M. 5·70, of rich illuminating-gas M. 16·7 and M. 21·7. By using water-gas, therefore, one can accomplish all boiling, heating or evaporating for *one-half* the money, all melting for about *one-quarter* the money, against the use of illuminating-gas. (It will be seen that this is only the result of the difference in the price of the two gases. For from Experiment 1, it follows that the pyrometric value of the coal-gas is 2·5 times as high as that of the water-gas.

G. A. K.

ALBANO BRANDO, described in the *Zeitschrift für Mineral. und Krystallogr.* **12,** 234, artificial crystals of Nickelantimonide, which occurred in the hearth of furnaces used for melting antimonial worklead, at the works of "Mechernich." These crystals are identical with the mineral *Beithauptite* They are 5–25 mm. long, 0·1 to 0·5 mm. thick, color between steel-blue and copper-red, adamantine lustre. After digesting the crystals in hydrochloric acid for removing adhering impurities, they contain 60·89 per cent. Sb, 30·01 Ni, 0·11 Co, 5·39 Pb, 1·17 Cu, 1·24 Fe. Total, 98·81. Spec. Gr. 8·21. The crystals are holohedral *hexagonal* combinations of ∞ P. $\frac{3}{2}$ P. 2 P.

J. HOCKAUF, *ibid*, page 240, gives a crystallographic and chemical study of *Botryogen*. This mineral occurs as secondary product in the copper mines of Fahlun, Sweden, and was described by Berzelius, 1815. This ferri-sulphate occurs in botryoidal or grape-shaped masses. The berries are one-half centimetre diameter, and are made up of radially arranged crystals. The surface is covered by a mealy, whitish yellow crust, but underneath this the small crystals are transparent, and of hyacinth-red color. The author inclines toward the assumption of the asymmetric system instead of the monosymmetric system of previous authors.

The analyses lead to the formula—$Mg\,Fe\,S^2\,O^8 + Fe^2\,S^2\,O^9 + 18\,H^2O$, whilst Berzelius gave $\overset{II}{Fe}{}^3\,S^2\,O^9 + 3\,\overset{III}{Fe}{}^2\,S^2O^9 + 36\,H^2O$, neglecting magnesium, calcium, and manganese in the calculation.

GEO. A. KOENIG, Philadelphia, shows in a preliminary paper (*Proceedings Academy Natural Sciences*, Philadelphia, 1886, p. 355), that the so-called *Schorlomite*, of Magnet Cove, Ark., is to be considered as a melanite garnet, in which titanium replaces both ferric iron and silicon. The presence of an oxide which reduces potassium permanganate has been overlooked by other

analysts or attributed to ferrous iron, but here it is shown that if this reducing power be attributed to titanic sesqui-oxide, the formula becomes that of a melanite, and the fact that the percentage of titanium varies from seventeen to twenty-seven per cent. becomes intelligible. Thus the composition of one sample of the mineral is 25·80 $Si\,O^2$, 12·46 $Ti\,O^2$, 4·44 $Ti^2\,O^3$, 1·00 $Al^2\,O^3$, 23·20 $Fe^2\,O^3$, 31·4 Ca O., 1·22 Mg O., 0·46, Mn O. Total, 99·98.

G. A. K.

THE GREAT VALUE OF ISOCHROMATIC PLATES in micro-photography has been demonstrated by Dr. Crookshank, who exhibited to the Royal Microscopical Society of London, micro-photographs of bacteria, obtained without staining the objects with aniline as in Koch's process, and he has still more recently exhibited a photograph showing the flagella of a vibrio. C. F. H.

A NOVEL AND VALUABLE APPLICATION OF PHOTOGRAPHY has been made by the Century Company, combining the complete preservation of valuable copy, against accidental loss or injury by fire or otherwise, with the greatest convenience in storage and handling. Over 25,000 sheets of copy of a work on its way through the press with interlineations, corrections and additions, have been photographed on a reduced scale, of only 1¾ x 2 inches to the page, but easily legible upon magnification. C. F. H.

IT WAS PREDICTED by Sir David Brewster, that a camera with only a pin-hole and without lenses would become the favorite instrument of the photographer, if photographic processes should become sufficiently sensitive to permit. Now that gelatine plates afford all needed sensitiveness, Capt. Colson, of Paris, has recently tested the method, and, in a brochure embodying his results, gives as an illustration, a photograph of the "Dome des Invalides" with an aperture of ·3 of a millimetre, and the plate 0·13 metres from the aperture, with an exposure of twenty seconds. The picture as a general view of the subject has a value, but will hardly impress favorably persons accustomed to the exquisite details and definition of modern photographs. Whilst in some cases absence of distortion and width of angle might give it a value, there would be other optical defects arising from illumination of bright points or small surfaces. C. F. H.

THE VAPOR DENSITY OF ZINC.—Justus Menshing and Victor Meyer (*Berl. Ber.* 3,295) have determined the vapor density of zinc, using the porcelain apparatus described by V. and C. Meyer (*loc. cit.* **12.,** 1,112) in a furnace capable of producing a temperature about 1,400° C. The apparatus was filled with pure nitrogen, and the vaporization of the zinc took place quickly and regularly. In one experiment, in which the temperature was not raised to the full power of the furnace, the density found was 2·41; in another, conducted at the highest attainable temperature, the density was 2·36. These figures assign the value Zn for the molecular formula of zinc vapor; theory would require the number 2·25. The three metals, whose vapor densities have been determined, (mercury, cadmium and zinc) have, in the gaseous state, molecules containing but a single atom. W. H. G.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, February 16, 1887.*]

HALL OF THE INSTITUTE, February 16, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, 142 members and 115 visitors.

New members elected since the last report, ten.

MR. JOHN JACOB HALTZAPFEL, of London, on the recommendation of the Board of Managers, was elected a corresponding member.

On behalf of the Committee on Meteorology, the Secretary made an oral report of the committee's work, in reference to the establishment of a "State Weather Service." In connection with this work, an Act had been drafted which contemplated financial aid from the state in carrying on the proposed service. The following is the text of the Act referred to, which, it is hoped, by the committee, will receive the favorable consideration of the Legislature, viz :

AN ACT

To establish a STATE WEATHER SERVICE in this Commonwealth, for the purpose of increasing the efficiency of the United States Signal Service, by disseminating more speedily and thoroughly the weather forecasts, storm and frost warnings, for the benefit of the citizens of this state, and for the purpose of establishing and maintaining in each county thereof meteorological stations for the collection of climatic data, and making an appropriation therefor.

WHEREAS, By reason of the limited facilities of the United States Signal Service, the practical benefits to be derived from the weather forecasts, storm and frost warnings, issued from the Chief Signal Office, at Washington, D. C., are greatly restricted, especially in the agricultural districts, by the want of proper means for disseminating these official reports promptly ; and,

WHEREAS, By the organization of a STATE WEATHER SERVICE, co-operating with the United States Signal Service, the weather forecasts, storm and frost warnings hitherto accessible only to a very small proportion of our people, may be much more rapidly and widely disseminated throughout the state, whereby the value of the same to the agricultural and other interests will be largely increased ; and,

WHEREAS, The climatology of the state has never been observed and recorded in as thorough and systematic a manner as is necessary for the best promotion of the various industries: and

WHEREAS, The STATE WEATHER SERVICE, already established and maintained by state aid in Alabama, Illinois, Indiana, Iowa, Minnesota, Mississippi, Missouri, Nebraska, Massachusetts, Ohio, Tennessee and others, co-operating with the United States Signal Service, have proved of great value to their citizens, especially to the farmers, who stand most in need of prompt and accurate information of anticipated climatic changes for the protection of their crops, and who are most directly benefited thereby; and,

WHEREAS—At the request of the Chief Signal Officer, the FRANKLIN INSTITUTE, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, has proposed a plan for the organization of an efficient WEATHER SERVICE for this state—therefore,

Be it enacted, etc.

Section 1. That the Secretary of Internal Affairs of this Commonwealth be and is hereby authorized and directed to name and appoint, on the recommendation of the FRANKLIN INSTITUTE, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, one, or more, competent observers in each county of the state, for the purpose of taking, recording and transmitting observations of the atmospheric pressure, temperature, humidity, rainfall, wind and other meteorological phenomena occurring in their respective localities; and the Secretary of Internal Affairs is hereby authorized and directed to purchase and furnish to each of said observers, such standard meteorological instruments as are used by the United States Signal Service, and such signal flags and other necessary equipments, and such necessary clerical expenses as shall be designated and approved by the said FRANKLIN INSTITUTE.

Sec. 2. The central office of the STATE WEATHER SERVICE shall be located in the City of Philadelphia, at which the weather forecasts and warnings of the U. S. Signal Service shall be received, and from which the same shall be disseminated throughout the state, and to which the STATE WEATHER SERVICE observers shall send their observations.

Sec. 3. The management of the work of the Pennsylvania STATE WEATHER SERVICE shall be under the supervision and direction of the FRANKLIN INSTITUTE of the State of Pennsylvania, for the Promotion of the Mechanic Arts and the said FRANKLIN INSTITUTE is hereby authorized to make such use of the information thus collected by the publication of a Weather Review, and by other proper means, as will best promote the usefulness of the service to the citizens of the State. And the services of the said FRANKLIN INSTITUTE, and of the said observers of the STATE WEATHER SERVICE shall be made without compensation.

Sec. 4. The sum of *three thousand dollars* be and the same is hereby appropriated for the purpose of carrying into effect the provisions of this Act, to be expended on the warrant of the Secretary of Internal Affairs drawn upon the State Treasurer.

The Committee has likewise proposed to the Pennsylvania Railroad Company, a plan for the considerable extension and improvement of the present method of disseminating the daily weather reports along the lines of this railroad. To this proposition, which involves the display of the signal flags at stations receiving the weather bulletin, no definite response has yet been received.

The LaCour-Delany Committee made a report of progress and was continued.

THE PRESIDENT announced the following appointments on committees for the current year:

STANDING COMMITTEES OF THE FRANKLIN INSTITUTE FOR THE YEAR 1887.

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	John H. Cooper,
Frederick Graff,	F. A. Genth,	C. Chabot,
Geo. A. Koenig,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Koenig,	N. H. Edgerton,
Isaac Norris, Jr.,	Otto Lüthy,	John Goehring,
John C. Trautwine, Jr.	E. F. Moody,	Morris L. Orum,
Chas. E. Ronaldson,	H. Pemberton, Jr.,	Chas. J. Shain,
Wm. P. Tatham,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.

Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	Lorin Blodget,	Hugo Bilgram,
George Burnham,	Charles M. Cresson,	A. B. Burk,
George V. Cresson,	Edwin J. Houston,	Geo. V. Cresson,
Cyrus Chambers, Jr.,	Isaac Norris, Jr.,	G. M. Eldridge,
Wm. Helme,	Alex. E. Outerbridge, Jr.,	Dr. Persifor Frazer.
Wm. B. Le Van,	J. S. W. Phillips,	Fred'k Graff,
Alfred Mellor,	Joshua Pusey,	Henry R. Heyl,
Henry Pemberton,	M. B. Snyder,	Washington Jones,
Wm. Vollmer,	Wm. P. Tatham,	G. H. Perkins,
John J. Weaver.	Wm. H. Wahl.	Chas. J. Shain,

Mr. PEDRO G. SALOM, of Philadelphia, read a paper on "The Julien System of Electric Transmission," which, with discussion thereon, has been referred to the Committee on Publications.

Mr. FRED'K E. IVES, of Philadelphia, read a paper on "Heat-Photography," embracing the results of some further researches in photographing with phosphorescent substances. The paper appears in this impression of the JOURNAL.

Mr. CARL HERING, of Philadelphia, by request, described and illustrated by experiment, the principle of the electric-lighting system of ZIPPERNOWSKI–NERI, in which alternating currents of high tension are converted, by an induction apparatus, into currents of low tension, suitable for incandescent lighting.

Mr. CHARLES RICHARDSON, of Philadelphia, described an ingenious modification of a dynamo-electric machine, which was used in this experiment, by which it was made practicable to obtain from it either direct or alternating currents. The subject was referred for publication.

THE PRESIDENT expressed the gratification of the INSTITUTE, on account of the presence at the meeting, of the members of the NATIONAL ELECTRIC LIGHT ASSOCIATION, now holding its sessions in Philadelphia, and extended to the Association a cordial welcome to the INSTITUTE. PRESIDENT MARSHALL, of the Association, responded with appropriate remarks.

The SECRETARY'S REPORT embraced some comments on the alleged successful demonstration, in London, of the claims of MR. CASTNER, for the cheap production of the metals of the alkalis; and on the present general adoption throughout the United States of the Sellers, or United States standard of screw threads, recommended for general adoption by the FRANKLIN INSTITUTE, in 1864. The consideration of this subject was called forth by a letter lately received from the SOCIETY OF GERMAN ENGINEERS, of Berlin, inquiring for information, and referring to an article published in a recent impression of (London) *Engineering*, in which the system of Sellers (now known as the FRANKLIN INSTITUTE, or United States Standard) was asserted to have failed in practice, and to have been abandoned. The correspondence on this subject has been approved for publication, and will shortly appear in the JOURNAL.

Adjourned. WM. H. WAHL, *Secretary*.

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(*Continued from Vol. CXXIII, page 88.*)

GROUP 12*b*.—GAS APPARATUS, INCLUDING HEATING AND COOKING STOVES, BURNERS FOR ILLUMINATION, ETC., NATURAL GAS BURNERS AND FURNACES.

Judges:—Lemuel Stephens, *Chm.*, Luther N. Cheney, W. H. Blake, M. D., Moses G. Wilder, Joseph Bond, Jr., Joseph Zentmayer.

The Committee of Judges appointed to examine the objects classified as group 12*b*, respectfully report as follows:—

THE FERRACUTE MACHINE CO., BRIDGETON, N. J.

Egg-Cooker with Gas-Stove.—The gas stove requires no special notice, any other mode of applying heat may be substituted.

The egg-boiler consists of a moon-shaped disc resting upon a spiral spring, which is supported by a central post. Around the outer rim of the disc are holes in which the eggs are placed, and the "boiler" is then put in a vessel containing boiling water.

Pressure upon a knob at the top of the post then depresses the disc below the surface of the water, where it is secured by a trip-catch. Above the disc is a bar or yoke, pivoted upon the central post, from one end of which depends a bucket, having a small hole in its bottom, which serves to gradually fill the bucket with water. Upon the opposite end of the yoke is a counterpoise, which slides upon a registered scale; its distance from the centre regulates the pressure of the bucket upon the water, and determines the length of time required to fill it, whether one, two, or more minutes. When the bucket is filled, its weight overcomes that of the counterpoise, the yoke is tilted, the trip-catch released, and the spring lifts the disc and eggs out of the water; at the same time the bucket being hung a little out of centre, tips, and empties itself, and the "boiler" is ready to be refilled.

This automatically acting contrivance is ingenious, and secures uniformity and exactness in boiling eggs.— (*Honorable Mention.*)

J. M. FOSTER.

Lighting Beacons and Buoys.—The committee have examined the Foster system of lighting beacons and buoys, with compressed gas, and were impressed with the importance of this invention as affording the means of guiding the mariner, and saving him from shipwreck in darkness and storm, and thus contributing largely to the welfare of mankind. If this invention could claim the merit of novelty or originality, its merit would go far to establish Mr. Foster's claim to the highest award within the gift of the INSTITUTE.

The depth to which the more slender cylinders of Mr. Foster descend into the water, and the great weight attached to the bottom, insures steadiness of the light in a storm.

Foster's Compressed Gas Compressor, and Foster's High Pressure Gas Governor, are both perfectly effective, and contain features of originality worthy of recognition. On account of these valuable improvements in the Foster system, your committee would recommend the award of— (*A Bronze Medal.*)

GOODWIN'S GAS STOVE AND METER COMPANY.

Goodwin's Gas Stove and Meter.—Mr. W. W. Goodwin exhibited a great variety of gas apparatus, used advantageously for heating, cooking and lighting. The corrugated copper reflector that can be used in the roasting ovens, is specially adapted for heating the room and diffusing a cheerful light.

A small pipe leading into the flue carries off the products of combustion and keeps the air odorless and pure. The cooking stoves and ranges presented were of many sizes, adapted to the wants of private families and largest hotels, on which every variety of roasting, baking and boiling may be carried on simultaneously, without any trouble in regulating the heat, and without emitting odors.

The comfort, neatness and economy of cooking and heating by gas are very fully attested by the certificate of those who have used the Goodwin's apparatus, and the exhibition to the committee of the many appliances in gas, for household economy, impresses them most favorably. The cheerful light and heat of an open fire were beautifully illustrated by an incandescent bed of asbestos or pumice stone.

Mr. Goodwin presented tabulated experiments in cooking a great variety of articles of food on a Peerless coal range, and one on a Sun-Dial gas stove, by which a saving in cost of fuel, in time required, and in loss by waste in cooking, is shown in favor of gas.

Mr. Goodwin states that from the average of his experiments, he finds that meat roasted by coal fire loses thirty-three and one-third per cent., while the same cooked by gas, loses only fourteen per cent., and retains its juices and flavor more perfectly. This estimate of the saving by gas seems to us excessive, but an actual saving to some extent is undoubted.

For the extensive and varied display of useful, economical and ornamental apparatus for the consumption of gas—

(*A Silver Medal.*)

THE GLOBE MANUFACTURING COMPANY.

Globe Gas Toaster and Stove.—A removable plate of planished iron or copper, supported on a burner and adapted to give great heat and no smoke. The bread to be toasted lies upon wires close

to the copper plate. When used upon a Bunsen or other heating burner, it operates nicely, and is a very handy little appliance.

(*Honorable Mention.*)

HALL & CARPENTER, PHILADELPHIA.

The Retort Gas Soldering Iron Furnace.—This furnace consuming ten feet of gas per hour, it is said, will thoroughly heat two two-pound irons in four minutes, and will keep the irons hot, consuming six feet of gas per hour.

This furnace can be run with gas cheaper than a furnace heated with charcoal. It is much cleaner, more convenient and safer; it is always ready, being extinguished and lighted in an instant.

(*Honorable Mention.*)

Your Committee on Gas Utilizing Apparatus have to report the following tests of gas burners, together with their recommendations based in each case upon tests and examinations of the burners.

ADOLPH WASSERMAN, PHILADELPHIA, PA.

Wasserman's Regenerative Gas-Lamp.—This is essentially an argand burner, having a circular flame, the air being admitted as in the common argand. One current passing up centrally, supplies oxygen to the interior of the flame; another current passes up upon the outside, and supplies oxygen to the exterior surface; this last current is deflected just at the bottom of the flame by a circular sheet metal shell, which surrounds the burner, so that the air is brought more in contact with the flame than with the common burner of the argand type.

In the centre of the burner, springing upward from the base, is a metal pipe, which expands toward the top into a hollow cone of considerable size, and which reaches the top of the flame. This cone is surrounded by a shell of porcelain, or other heat-resisting material. The flame, passing up outside of this cone, is not in contact with it, being of a larger diameter, but the heat of the flame is such as to raise the surface of the cone to a high temperature, and the ascending current of air, which rises from the base of the burner, freely in contact with the cone, is heated as it rises. The cone also gives the air a direction toward the surface of the

flame, and thus the combustion of gas takes place at a higher temperature and produces a higher degree of incandescence.

The burner is adapted to the fixtures in ordinary use, and requires no especial training or care to secure good results. Our tests, made October 26, 1885, gave the following results:

City gas this day gave	16·20 candles.
Candles per foot of gas, ...	3·20

TEST NO. 1.

Gas burned per hour, ...	10·5 cubic feet.
Candle-power, ...	38·06
Candles per foot of gas, ...	3·62

TEST NO. 2.

Gas burned per hour.	9 cubic feet.
Candle-power, ...	38·95
Candles per foot of gas, ...	4·32

In view of the fact that this comparatively simple burner shows an efficiency equal to that of Sugg's four-ring argand burner, which consumes ninety-five feet of sixteen-candle gas per hour, we would recommend the award of the Bronze Medal of the FRANKLIN INSTITUTE to Mr. Wasserman, with the diploma of the INSTITUTE for his invention.

KITSON & CO., PHILADELPHIA, PA.

Albo-Carbon Gas-Lamp.—This lamp, shown in a variety of sizes during the Exhibition, consists of one, or a group, of gas burners, so arranged that the heat of the various flames shall be partially utilized to vaporize and render volatile a quantity of naphthalene, which is contained in a metal reservoir, forming a part of the fixtures supporting these burners. This is done by extending out over the flame, a portion of the metal structure of the fixture, so that the metal may be heated, and thus communicate its heat to the naphthalene. The gas on its way to the burners passes through the reservoir, and, becoming charged with the vapor, burns with a brilliant white light, of far greater power, than would be given by the gas itself.

The charging of the gas with the vapor of hydro-carbon, to increase its illuminating-power, is not new, and in this burner other hydro-carbon than naphthalene could be used, but the naphthalene being a solid at temperatures below 176° F., and vaporizing at

414° F. only, is more suitable for the purpose, as it can be handled and transported without danger.

Our tests were made upon a small fixture of one burner, because the large burners could not be tested upon our photometer, without making extensive alterations, and we were of the opinion that such changes were not necessary to determine the efficiency of the light, inasmuch as each group was made up of single lights of the same size as that tested.

Our tests made November 2, 1885, gave results as follows:

City gas candle-power,	17·25
Candles per foot of gas,	3·45
TEST NO. 1.	
Gas burned per hour,	4·80 feet
Candle-power,	29·70
Candles per foot of gas,	6·18
TEST NO. 2.	
Gas burned per hour,	4·95 feet.
Candle-power,	41·10
Candles per foot of gas,	8·33
Naphthalene consumed for 1,000 feet of gas,	2·88 pounds.
Cost of same, at twelve cents per pound, for 1,000 feet,	34·5 cents.
Cost of city gas, \$1.60. Cost of carburetted gas,	\$1.94·5 cents.

In view of the foregoing, your committee would recommend to Kitson & Co., for their albo-carbon gas-lamp, the award of the—

(Bronze Medal and Diploma.)

SIEMENS-LUNGREN GAS-LIGHT COMPANY, PHILADELPHIA, PA.

The Siemens' Regenerative Gas Lamp.—This lamp shows most strikingly the great progress that has been made in methods of gas lighting consequent upon the development of the electric light. Invented at a time when the highest efficiency attained was but little over four candles per foot of gas, almost at a single stride, Frederick Siemens raised the standard to nearly or quite ten candles per foot (with the most suitable gases for use in this lamp). In so doing he not only secured great economy in lighting large spaces, but gave improved ventilation, and also a far better quality of light.

With his long experience in the adaptation of the regenerative principle to furnaces, he brought to the problem a knowledge which gave him a comprehensive grasp of the subject in all its bearings,

and enabled him not only to produce the best gas light then known, but also to illustrate forcibly certain principles, which alone would enable us to secure the highest results in illumination by the use of gas.

It is not possible to clearly explain the construction of this lamp, without detailed drawings, but inasmuch as its form can be greatly varied, without changing the principle of its action, we think a detailed description of the lamp, tested by us, is not necessary.

The central principle on which its efficiency depends, is the heating of the air and gas intensely, before they reach the zone of combustion, by bringing them into the lamp, and to this zone, in contact with metal surfaces heated to a high degree by the waste gases which are passing away from the flame.

The flame is therefore hotter and the light more intense.

This heating or regenerative action is also cumulative, and increases with the rising temperature of the flame, until, if there were no loss by radiation and the like, the heat would increase until the entire structure would be destroyed. Practically, the heat does not increase beyond a point which the lamp endures safely. The waste gases are conducted by a metal pipe to a flue, after they have done their work in the lamp, and the air of the room is left uncontaminated with the products of combustion.

A large number of lamps are used in the public squares of this city, notably, Franklin, Rittenhouse and Logan. These squares are made far more attractive and safer than before. They are also used in many other places in lighting buildings and spaces about them.

Our tests of this lamp were made on a bar photometer, with a length of 280 inches between the lamp and our standard. Our standard was a Sugg argand burner, rated to pass five feet of gas per hour.

Horizontal Tests of Siemens' Lamp, November 3, 1885:—

Candle-power of our Standard and City gas, . . .	17·71 candles.
Candles per foot of gas, ...	3·54

TEST NO. 1.

Gas burned per hour, ...	51·18 feet.
Candle-power, ...	364·65
Candles per foot of gas, ...	7·12

TEST NO. 2.

Gas burned per hour,	51·18 feet.
Candle-power,	463·11
Candles per foot of gas,	9·04

TEST NO. 3.

Gas burned per hour,	48·00 feet.
Candle-power,	396·52
Candles per foot of gas,	8·26

All of the above tests were made at one heating of lamp.

In view of the foregoing, your committee recommended the award of the Silver Medal of the FRANKLIN INSTITUTE, to the Siemens-Lungren Company for the Siemens regenerative gas lamp, togehter with a Diploma of the INSTITUTE.

SIEMENS–LUNGREN GAS-LIGHT COMPANY, PHILADELPHIA, PA.

The Lungren Inverted Regenerative Gas-Lamp.—This lamp owes its efficiency to the heating of the air and gas which enter the flame, by means of the waste heat which is leaving the lamp. Resembling in this respect the Siemens' lamp, it has peculiarities which render it noticeable, and increase its value to a marked degree.

The flame and the illumination is all below the structure of the lamp itself, there are no shadows, and the light thrown down from the suspended lamp is entirely unobstructed. The lamp is also of a form and structure, which admits of its use in a variety of places where the Siemens' lamp could not be used so conveniently. Finally, its efficiency is much higher than that of the Siemens lamp in small and medium lamps, such as are used in lighting offices, stores and apartments of moderate dimensions. Its value for general illumination is for this reason greater.

The quality of the light for brilliance, steadiness and color is unsurpassed, and the lamp itself is simple in its construction, and of a pleasing design.

In measuring the light of the lamp, your committee found it necessary to construct a photometer for the angular measurements. Horizontal measurements were made upon the bar photometer used in testing the Siemens' lamp. The flame of this lamp being entirely below the lamp, however, the horizontal rays of light do not represent its efficiency in actual use.

The series of measurements were made as follows:

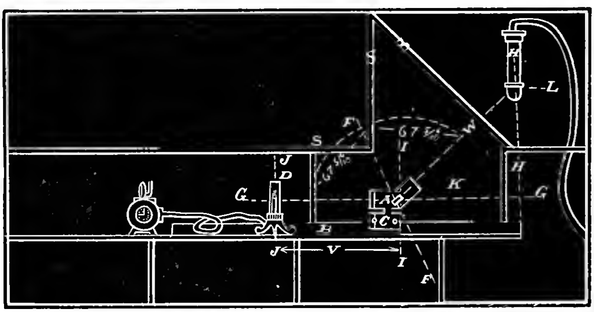
FIRST: HORIZONTAL, OCTOBER 31, 1885.

The lamp was suspended in line with the bar at the end, and its light was compared with that of the Sugg argand used in testing the candle-power of the city gas.

Candle-power of city gas, ...	17·69 candles.
Candles per foot of gas, ...	3·54
TEST NO. 1.	
Gas burned per hour, ...	16·44 cubic feet.
Candle-power, ...	124·71
Candles per foot of gas, ...	7·58
TEST NO. 2.	
Gas burned per hour, ...	17·85 cubic feet.
Candle-power, ...	155·84
Candles per foot of gas, ...	8·7
TEST NO. 3.	
Gas burned per hour, ...	17·25 cubic feet.
Candle-power, ...	157·62
Candles per foot of gas, ...	9·12

SECOND: ANGLE OF 45° BELOW THE HORIZONTAL LINE.

For this test we had a sight-box made, which was mounted stationary upon a bar as shown in the sketch. The screen in the sight-box *A* was placed coincident with the line *F. F.* Therefore the lights from the lamps *D* and *L* entering the sight-box at opposite ends thereof, the screen was illuminated equally when the carriage and its argand *D* were placed so that $V2 : W2 :: T : U.$



Photometer Used in Measuring Lungren's Inverted Regenerative Gas Lamp. Angle of 45° and Vertical. November 5, 1885.

A.—Sight-box stationary on photometer bar.

B.—Bar of photometer stationary on table.

C.—Wooden clamp to carry sight-box for adjustment.

D.—Standard argand, moves freely along the bar from end to clamp *C.*
L.—Lamp to be measured suspended over the bar.
F F,—Line through sight-box, 67° 30′ above horizontal line *G G.*
G G.—Horizontal line passing through centre of argand and sight-box.
H H.—Centre line of lamp to be measured.
I.—Perpendicular line passing through centre of illuminated screen.
J.—Centre of argand and pointer on carriage of same.
K.—Centre of screen in sight-box on line *G G* and *I I*
S S S.—Screen boards to cut off all but direct rays from sight-box.
T.—Candle-power of argand.
V.—Distance from *J* to *I.*
U.—Candle-power of lamp being measured.
W.—Distance from *K* to *L.*

All the distances having been accurately measured before the test, except that from *J* to *I*, the standard lamp, *D*, was moved along the bar in each reading until the illumination was equal upon the two sides of the screen, precisely as in the usual tests for candle-power with the common sight-box and candle, the difference being solely in the fact that our standard, and not the sight-box, was moved.

The average of ten observations in this way gave us the distance, *V*, from *J* to *I*, in each test. The other distance, *W*, being known already, the candle-power was readily determined.

The results were as follows:

45° Angle Tests, Lungren Lamp, November 5, 1885:—

Candle-power of city gas,	18·60 candles.
Candles per foot of gas,	3·72

TEST NO. 1.

Gas burned,	16·20 cubic feet.
Candle-power,	197·16
Candles per foot of gas,	12·17

TEST NO. 2.

Gas burned,	16·65 cubic feet.
Candle-power,	231·78
Candles per foot of gas,	13·09

TEST NO. 3.

Gas burned,	17·20 cubic feet.
Candle-power,	230·64
Candles per foot,	13·04

(3.) VERTICAL TESTS.

The lamp was suspended over the vertical end of a sight-box, so made that the horizontal rays from our standard argand, and

the vertical rays from the Lungren lamp fell, as in the previous test, upon opposite sides of the same screen, the screen in this case being at an angle of 45° to the lines of light falling upon it.

The light from the suspended lamp entered the sight-box, through a round hole in a wooden screen placed over it, and the standard argand was moved as in the previous tests in making each observation. The average of ten readings gave us the distance from which the candle-power was determined.

The results were as follows:

Vertical Test of Lungren Lamp, November 5, 1885:—

City gas, candle-power, ...	18·60 candles.
Candles per foot of gas, ...	3·72
Gas burned per hour, ...	16·00 cubic feet.
Candle-power, ...	223·86
Candles per foot of gas, ...	13·99

In view of the advantages of this lamp, as previously stated, and of the remarkable efficiency as shown in these tests, we would recommend the award of the Silver Medal to this lamp, together with the Diploma of the INSTITUTE.

Furthermore, in view of the fact that the Siemens-Lungren Company have established the manufacture of the Siemens and Lungren lamps in a way to supply the demand in all the required sizes thereof, and have thereby added a new and valuable industry to those already established in the city, we would recommend the award of the ELLIOT CRESSON GOLD MEDAL, and request the reference of our report to the Committee on Science and the Arts.

LEMUEL STEPHENS, *Chairman.*
LUTHEN L. CHENEY,
W. H. BLAKE, M. D.
MOSES G. WILDER,
JOSEPH BOND,
JOSEPH ZENTMAYER.

(*To be Continued.*)

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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THE SELLERS OR FRANKLIN INSTITUTE SYSTEM OF SCREW-THREADS.

The following correspondence has grown out of an inquiry addressed to the INSTITUTE by the Society of German Engineers of Berlin, and is self-explanatory. W. H. W.

BERLIN, W., den 22. October, 1886,
Wichmannstrasse 14.

An das FRANKLIN INSTITUTE, *Philadelphia* (*V. St. A.*), *15 South Seventh Street.*

Für die in unserm Vereine noch immer im Gange befindliche Agitation zur Aufstellung eines einheitlichen Schraubengewindesystems auf Grundlage des Metermaasses, würde es uns von hohem Werthe sein, die Verhandlungen und Beschlüsse eines verehrlichen FRANKLIN INSTITUTE über diese Frage kennen zu lernen; insbesondere würde es uns interessiren, zu erfahren, ob in den Ver. Staaten ein Standard-Gewinde aufgestellt ist, und zwar welches, und welche Geltung es bisher erlangt hat.

In der Zeitschrift *Engineering*, vom 10. September d. J., ist ein Aufsatz, welcher unter Anderem die Behauptung enthält, dass das von Sellers vorgeschlagene Gewinde, mit geraden Flächen statt der Whitworth'schen Abrundungen, als nicht bewährt befunden und wieder aufgegeben worden sei; auch hierüber wären uns Mittheilungen sehr erwünscht.

Mit Freuden bereit, auch Ihnen vorkommenden Falles zu Diensten zu sein, zeichnen wir Hochachtungsvoll,

DER VEREIN DEUTSCHER INGENIEURE.
Th. Peters.

[*Translation.*]

BERLIN, W., October 22, 1886.

To the FRANKLIN INSTITUTE, *Philadelphia* (*U. S. A.*), *15 South Seventh Street.*

In connection with the subject of establishing a uniform system of screw-threads based on the metrical system—which, for a long time, has been agitated by this society—it would be of the greatest value to us to be advised respecting any proceedings taken and conclusions reached by the FRANKLIN INSTITUTE upon this subject. It would especially interest us to learn if any standard has been adopted in the United States, and if so, what standard, and to what extent it has, up to the present time, received acceptance.

In *Engineering*, of September 10, 1886, there appears an article on this subject, in which the assertion is made, that the system of threads, proposed by Sellers—having straight surfaces instead of the rounded ones of Whitworth—had not been found to fully meet the requirements of practice, and had been abandoned. On this point, also, any information would be very acceptable. With the expression of our willingness to serve you, should the occasion offer itself, we subscribe ourselves,

With high regard,

THE SOCIETY OF GERMAN ENGINEERS,

Th. Peters.

The article in (London) *Engineering*, herein referred to, is given below, viz.:

In the year 1857, many of the leading engineers in England began to recognize the evil and the very great inconvenience which arose from various quarters through individual machine and engine makers using a separate system of screw-threads. So important did Sir Joseph Whitworth consider the matter, that he undertook to establish and introduce a uniform system of standard pitches and form of thread for use throughout the country. His first table was published in the same year, viz., 1857, and a second one in 1861, in which he gave fuller particulars, and proposed a few minor improvements. The main points to be considered in arranging such a system were, briefly:

(1.) The best and most suitable pitches or number of threads per inch of length for given diameters of bolts, the main object being to reduce the strength of the bolt as little as possible, and at the same time to make the threads of sufficient depth to prevent liability to "cross-threading" taking place, and to get a convenient thickness of nut which would stand at least as much longitudinal tensile stress as the bolt at the bottom of the thread. After very careful consideration on the part of Sir Joseph Whitworth, he decided upon a set of pitches, which were published in tabular form, copies of which are found in all engineering text-books. The following formula, taken from Unwin's *Machine Design*, page 117, gives a very close approximation:

Let d = the original diameter of the bolt.

$p =$ the pitch of the threads.

Then

$$p = 0{\cdot}08\ d + 0{\cdot}04,$$

and the diameter at the bottom of the thread,

$$d' = 0{\cdot}9d - 0{\cdot}05.$$

(2.) The form or cross-section of the thread best suited for practical purposes, which involved the consideration of ease of manufacture and reproduction, combined with security against damage by the comparatively rough treatment bolts and screws are subjected to. The form of cross section Whitworth adopted for ordinary purposes was that of a triangle, whose height was 0·96 pitch and the angle at the bottom of the threads 55° (see Unwin's *Machine Design*, page 117); one-sixth of these triangular sections was rounded off at the top and bottom. This system has been very widely and almost universally used for the last thirty years, the chief and only important exception to their universality being in the United States, where Sellers's threads are very much used; they are of a slightly different pitch, and form of cross-section, being an equilateral triangle with one-eighth of the depth cut off square, both top and bottom; the pitch is nearly $p = 0{\cdot}1\ d + 0{\cdot}025$, and the diameter at the bottom of thread $d_1 = 0{\cdot}87\ d - 0{\cdot}03$. (See Unwin's *Machine Design*, page 119).

The relative values of these two systems lie chiefly in the merits of round or sharp corners. We shall return presently to consider both systems in detail, but it is well to note here that the latter system is being discarded for one very similar to the Whitworth. This is briefly how the screw-thread question stands at the present time. However, in Germany and on the Continent of Europe generally, the English system of measurement in feet and inches is not in common use, but the metrical system is almost universal, viz., of meters with decimal subdivisions. Hence, a small body of German engineers have been for some time urging for a universal metrical standard of screw-threads, and consequently seek to overthrow the Whitworth system.

In 1874,* the München District Society of German Engineers, took up the matter, when they not only procured the opinions of the German district societies, but communicated with various well known Continental engineering societies, and at the same time sent out 2,000 circulars to owners of works to obtain their views upon the practicability of introducing a metrical system in the place of Whitworth's, maintaining that this system was not in general use; but the result of this inquiry was in favor of retaining the Whitworth system.

Out of the 2,000 circulars sent out, only 365 were returned, 316 of which were from makers who used the Whitworth system exclusively, and the remaining forty-nine retained the pitch, but used different diameters of bolts. Of the twenty district societies which were consulted, only six decided in favor of the metrical system. The practical effect of this inquiry was to set the Whitworth system on a firmer basis than ever. In spite of this, however, the Karlsruhe District Society brought forward motions in favor of the metrical system at the principal meeting of the Society of German Engineers in 1877, but they were at once dismissed by them. Again, in 1885, the same society brought up the matter under a rather a different aspect, viz., not whether it was

* *Vide* a paper "On the Thread Question," by J. H Mehrtens, engineer, of Berlin

desirous to introduce a metrical system of screw-threads, but what metrical system shall be introduced, implying that the former was a settled matter, and the only matter requiring consideration was the details of the system.

The directorate thought it desirable to appoint a special commission to inquire into it. The main objections brought against the Whitworth system by the commission and the Karlsruhe Society, were briefly:

(1.) The Whitworth system is not universally used in Germany, and consequently great disorder prevails.

(2.) The Whitworth system being measured in inches, it is inconvenient for metrical measurements.

(3.) The cross-section of the Whitworth thread is difficult of manufacture.

The first objection has been dealt with above in the remarks on the action taken by the Karlsruhe and München District Societies, and, again, the Whitworth system is universally used by the German railways and dockyards, and unless a general desire is shown for a metrical system of threads, it is evidently quite useless for a handful of obscure scientific men to attempt a radical change in such an important matter.

The second objection, on the surface, appears slightly more justifiable, but even that is extremely insignificant when more closely examined and viewed from a different standpoint. This matter does not stand upon the same ground that it did ten years ago, when the whole of the bolts and screws in use were constructed in small quantities as they were required at the various machine and engine works; to-day, the case is totally different, as only a very small percentage are constructed in this way; they are almost entirely bought from special screw-makers, who turn out better and cheaper work than is possible for individual machine shops. Thus, the imaginary difficulty lies entirely in the screw-makers' hands. They do not complain; why, then, should those whom it does not affect to any appreciable extent?

If a new universal system of screw-threads must be adopted, then it should not be tied down to any special system of measurement, but should rather be designed on a system of standard gauges of various grades, similar to our Birmingham wire-gauge system. Some of the German engineers complain that a considerable number of Whitworth bolts and nuts purchased from one firm of screw-makers, will not fit those purchased from another firm, and lay the blame to the system, but this is decidedly unjust, for it is evident to any practical engineer that the fault lies not in the system itself, but with the manufacturers for not using standard screw-gauges as Sir Joseph Whitworth advocated in his original report on the subject. None can say but what the proposed new system would be quite as faulty, perhaps even worse in this respect, as it has never been practically put to the test. If German engineers persist in their course and carry out this proposed scheme in the machinery they manufacture, they only will be the sufferers by ruining their foreign trade, for no foreigners will think of purchasing machinery which cannot readily be repaired by local engineers without sending to Germany for special bolts and nuts.

The third objection is totally unjustifiable, for thirty years of practice have most unmistakably proved the Whitworth form of cross-section to be

the best; the square-tipped thread, on the other hand, as advocated by the metrical system, has proved unsuccessful; it has been thoroughly tried by Sellers in the United States, where it has been found practically impossible to produce a good thread by screwing-apparatus; the sharp corners on the taps and dies rapidly break away, when a very imperfect thread must naturally follow. The present state of affairs in America conclusively shows the system to have been a failure, and all the leading machine-tool makers there are supplying nothing but the **V**-thread, very similar to Whitworth's.

Again, the strength of the bolt is reduced more by the square-cornered than by the rounded thread, although the sectional areas of the bolts at the bottom of the threads are the same; for example, it is always found to be absolutely necessary in the preparation of test specimens for tensile tests to have the corners well rounded off; if not, the specimen almost invariably breaks short off at the square corner. With good tools and good men to use them, there is no difficulty whatever in producing the Whitworth cross-section of thread. The round at the bottom of the thread is easily produced by a rounded point to the screw-cutting tool, a gauge for which is carried by every turner in his waistcoat pocket. The round at the top of the thread is produced by the chaser, which is itself cut by a standard hob, and consequently reproduces the correct form of cross-section on whatever work it is used.—*Engineering, Sept. 10, 1886.*

SECRETARY'S OFFICE, HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, January 31, 1887.

The Society of German Engineers:

GENTLEMEN:—In response to your letter of October 22d ult., asking to be informed respecting any proceedings taken and conclusions reached by this INSTITUTE, upon the subject of establishing a uniform system of screw-threads, whether any standard has been adopted in the United States, and if so, what standard, and to what extent it has, up to the present time, received acceptance, also referring to an article in *Engineering*, of September 10, 1886, with quotation therefrom, I have the honor to report:

The proceedings taken by the FRANKLIN INSTITUTE, with reference to a uniform system of screw-threads, were inaugurated by a paper upon this subject, by Mr. Wm. Sellers, read by him before the INSTITUTE at its regular monthly meeting, held April 21, 1864, (see copy of the JOURNAL for April of that year, forwarded, with other papers hereinafter referred to, by book-post on the 31st inst.) This was followed by the appointment of a committee to investigate and report. The report of this committee will be found in the number of the JOURNAL for January, 1865, forwarded as above, and this ended the proceedings so far as the FRANKLIN

INSTITUTE was concerned. Early in 1868, the Secretary of the Navy of the U. S., appointed a Board of Engineers, to investigate and report upon a system of screw-threads, which might with advantage be adopted by that department of the Government, and this Board reported May 9, 1868, recommending the system advocated by Sellers, and approved by this INSTITUTE (see copy of report forwarded as above). This report was approved by the Secretary of the Navy, and thenceforth it has been the standard for the U. S. Government, not only for the Navy Department, but for all other departments, excepting for small arms and other specific requirements, where a much finer thread is necessitated. This action by the Government was followed by its general adoption in the large private establishments all over the country engaged in constructing the heavier classes of machinery.

In April, 1869, the Pennsylvania Railroad Company ordered a set of gauges to the new form of thread, and adopted the system upon all of its lines, and this was followed by various other railroads throughout the country, until in 1872, the Master Car Builders' Association recommended the Sellers or FRANKLIN INSTITUTE System of Screw-Threads and Bolts as a standard. The progress thereafter in this direction is shown by the *Report of the Proceedings for 1885*, forwarded as above, and similar action was taken by the Master Mechanics' Association.

To answer your inquiry, "to what extent it has, up to the present time, received acceptance," and also "the article in *Engineering*" before referred to, the Secretary of the INSTITUTE addressed the following letter to the proper officers of the principal railroads in the United States, and to several individual manufacturers:

PHILADELPHIA, December, 1886.

To the Superintendent of ———— Railroad Company:

DEAR SIR:—The Society of German Engineers of Berlin has made certain inquiries of the FRANKLIN INSTITUTE, concerning the Standard Screw-Thread recommended for general adoption by the FRANKLIN INSTITUTE in 1864, and adopted by the Navy Department of the United States in 1868, among which inquiries the durability of the straight surfaces as compared with the rounded ones of Whitworth, is questioned. It is probable that the straight surfaces of the standard thread would show a modification of form to the eye which would not be observable upon the curved surface of the Whitworth thread; but, as some contribution to this inquiry, it would be of interest to know whether the standard thread has been adopted upon your road, and whether you have experienced any difficulty in practically maintaining the

form of the thread, or at least sufficiently so as to make the nuts interchangeable. If you find that the straight surfaces are more difficult to maintain than the curved ones of the Whitworth thread, would this be counterbalanced by the greater facility for making the straight thread with a single tool over that of the curved thread which requires two (2) tools, and which form of thread can most easily be constructed and tested, for accurate conformity with a standard of its form? Any information you can give me in connection with this subject will be highly appreciated by, Yours truly,

WM. H. WAHL, *Secretary.*

IN RESPONSE to this letter, he has received replies from the following railroad companies:

Pennsylvania Railroad Company, operating and controlling 7,346 miles of railroad.

Chicago, Milwaukee and St. Paul Railway Co., 4,921 miles.

New York Central and Hudson River Railroad Co., 993 miles.

Chicago, Rock Island and Pacific Railroad Co., 1,383 miles.

Delaware, Lackawanna and Western Railroad Co., 889 miles.

Louisville and Nashville Railroad Co, 3,727 miles.

Chicago, Burlington and Quincy Railroad Co., 3,646 miles.

New York, Lake Erie and Western Railway Co, 1,601 miles.

He has also a reply from one of our largest manufacturers of bolts and nuts, and one from our most important manufacturers of taps and dies. The article in the *Railroad Gazette*, of September 24, 1886, referred to by the latter, is forwarded by book-post with the other paper hereinbefore referred to.

THE LETTERS received in response to the Secretary's inquiry are as follows:

Louisville and Nashville Railroad Company. Harvey Middleton, Superintendent Machinery.

LOUISVILLE, Ky., December 6, 1886.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Yours of December 14th is at hand and noted. We adopted the United States Standard thread, sometimes called the FRANKLIN INSTITUTE Thread, about five (5) years ago, in all the shops of our lines, and have used it ever since. We have found no difficulty whatever from the wearing of the taps and dies as long as they are not used beyond a proper length of time. Of course, as taps and dies wear away, it will make a slight difference in the form of the thread; but, I do not believe that that change is any greater or can give any more trouble than in the case of the Whitworth thread referred to. We have experienced no difficulty in the interchange of nuts and bolts on account of the slight change that occurs in the form of the thread in the wearing of the taps and dies. Of course, any form of thread will change slightly from the wearing of the taps and dies, and it is impossible to avoid

that by any form of thread used. A straight side to a thread is easier to make than a rounding side, and therefore more likely to be perfect. A straight side to a thread, it seems to me, will change as little, perhaps less, than a rounding side. The proper way to keep threads as near the original as possible is to throw away the taps and dies before they are worn to such an extent as will make any practical difference in the shape of the thread. This is a matter that is sometimes overlooked. The expense of taps and dies is not great, and only perfect taps and dies should be used; and as soon as the wear amounts to enough to make an appreciable difference in the form of the thread, they should be thrown away and renewed. We have made it a rule to purchase from reliable manufacturers nearly all of our taps and hobs for cutting dies, and we have been particular to throw away taps as soon as they are worn to any considerable extent, and use new ones. The same in regard to dies; as soon as the wear amounts to anything, we re-cut them, dress them up and then they are as good as new. It seems to me a flat-top form of thread will change as little as a thread that runs to a point. It will change less in diameter from out to out of the thread. With a sharp-top thread, when the sides wear away slightly, it reduces the height of the thread. With a flat-top thread the wear of the sides will not reduce the diameter from out to out of the thread, but will simply make the thread a little thinner at the point, etc.

Yours truly,

R. WELLS, *Superintendent Machinery.*

Delaware, Lackawanna and Western Railroad Company. Office of Machine Shops.

SCRANTON, Pa., December 8, 1886.

MR. WM. H. WAHL, Secretary of the FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Replying to yours of the 4th inst., in regard to the Standard Screw-Thread, would say, the United States Standard has been adopted on this road and gives entire satisfaction. It is much easier to make, and the tools to make it less expensive to keep up.

Yours truly, CHAS. GRAHAM, *Master Mechanic.*

Chicago, Milwaukee and St. Paul Railway. Office of General Master Mechanic.

WEST MILWAUKEE, Wis., December 11, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE of Pennsylvania, Philadelphia, Pa.

DEAR SIR:—I make the object of this, to reply to your favors of the 4th inst. In 1871, the locomotive department of this company adopted what is known as the United States, or FRANKLIN INSTITUTE Standard, for Diameters and Threads, and have continued to use it up to the present time. We have experienced no particular difficulty in the interchanging of nuts. Should there be any difficulty in maintaining the straight surfaces of the threads more than those of the Whitworth type, it would in our opinion be more than counterbalanced in costing less to maintain the straight surfaces than the

curved. We are of opinion, however, that the Whitworth thread is the strongest, *i. e.*, less liable to fracture the bolt.

I am, yours truly, I. M. LOWRY, *General Master Mechanic.*

Chicago, Rock Island and Pacific Railroad. Master Mechanic's Office.

CHICAGO, December 15, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—About three years ago we adopted the United States Standard Thread for Bolts and Nuts, and have so far experienced no difficulty whatever in practically maintaining the form of the thread. I have not yet seen a case where a bolt had worn so that nuts were not interchangeable.

I have had very little experience with the Whitworth thread, but feel certain that any slight advantage in durability or strength which it may have over the United States Standard, is far outweighed by the inconvenience in its construction. Regretting that I cannot give you more scientific and interesting data, I am, Yours truly,

THOS. B. TWOMBLY, *General Master Mechanic.*

Chicago, Burlington and Quincy Railroad Company. Office Superintendent Motive-Power.

AURORA, Ill., January 5, 1887.

FRANKLIN INSTITUTE of Pennsylvania, WM. H. WAHL, Secretary, Philadelphia, Pa.

DEAR SIR:—Yours of the 4th duly received, asking whether this road has adopted the United States Standard thread, and whether we have experienced any difficulty in maintaining the form of the thread.

The United States Standard or FRANKLIN INSTITUTE Thread was adopted in the car department of the Chicago, Burlington and Quincy, in 1883, and since then has been gradually introduced into the locomotive and track departments. For two years past we have used this thread for all purposes. We have had no difficulty whatever in maintaining the form of the thread, that is to say, we can forward to any point on our line new nuts, which can be used satisfactorily on old bolts. Our foremen all speak highly of the United States Standard, owing to the facility of maintaining a uniform shape.

One of our foremen at Burlington, Mr. Scholey, who has used the Whitworth thread in the old country, and the United States Standard in this country, says the latter is much more easily maintained.

We enclose you some correspondence from our master mechanics on this matter.

(A.) J. West, M. M., Burlington shop.

(B.) L. E. Johnson, M. M., Aurora.

(C.) C. F. Geyer, General Foreman Aurora Shop.

Yours truly, G. W. RHODES, *Supt. M. P.*

A.

Chicago, Burlington and Quincy Railroad Company. Locomotive and Car Department.

West Burlington, December 16, 1886.

G. W. Rhodes, Esq., Superintendent Motive-Power.

Dear Sir: Referring to attached letters in regard to screw-threads, I fully agree with Messrs. Johnson and Geyer in the matter of threads.

I have talked this matter over with our general foreman, Mr. Scholey, and he says that with our American or United States Standard, it is much easier to keep up taps and dies than with the Whitworth thread with rounded edges and angles, which he used in the old country, and a good fit is easier to make.

Yours, J. A. West.

Nuts.—United States Standard *vs.* Whitworth Thread.

B.

Chicago, Burlington and Quincy Railroad Company. Master Mechanic's Office.

Aurora, Ill., December 11, 1886.

G. W. Rhodes, Esq., Superintendent M. P., Aurora.

Dear Sir:—Returning your communication from the Franklin Institute, and, in reply to the same, would respectfully state that the United States Standard thread has been in use in the car department since 1883. During that time, we have experienced no difficulty whatever in practically maintaining the form of the thread; that is to say, that we can forward to any point a supply of new nuts, which can be used on bolts that have been in service since that time.

Foremen of other shops substantiate Mr. Geyer's statement, that it is much more difficult to maintain the curved surface of the Whitworth thread than the straight, or United States Standard. We have no absolute data on this subject, other than practical experience for the past three years. We are gradually changing the thread of bolts in all departments to the straight, or United States Standard. In doing this, we experience no difficulty or annoyance, as the men in each department keep a small quantity of old nuts with the old thread, so as to avoid throwing away bolts.

We undoubtedly shall eventually have nothing but the United States Standard thread in use in all departments.

I enclose you copy of Mr. Geyer's report.

Yours respectfully, L. E. Johnson.

C.

Aurora, Ill., December 9, 1886.

L. E. Johnson, Esq., Div. M. M., Aurora.

Dear Sir:—In regard to the enclosed, it is my opinion that the Whitworth Standard tap is very impracticable, as it is a hard matter to make them twice alike, therefore, much more expensive. It is true, if a nut and bolt is in constant use, it will wear about the shape of the Whitworth Standard, and it may be more durable. We have never, as yet, experienced any

trouble with the United States Standard thread. A new nut can always be substituted where an old one of the same size is taken off.

It will cost at least double to maintain the tools of the round or Whitworth thread, and, it is my opinion, it is not any better or stronger than the straight or United States Standard thread.

Respectfully yours, [Sgd.] C. F. GEYER.

SUBJECT—STANDARD SCREW-THREADS.

The Pennsylvania Railroad Company. Office of General-Superintendent of Motive-Power.

ALTOONA, Pa., December 20, 1886.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In reply to your letter of December 3d, would say, that in our experience we have had no trouble at all in maintaining the form of thread of the United States Standard, and the nuts we tap are perfectly interchangeable.

We think, the straight surfaces are much more easily maintained than the curved ones of the Whitworth thread would be, for the reason that it is easier to discover irregularities in straight than in curved lines, and it is quite easy to grind a thread cutting-tool to the straight lines of the standard thread.

Yours truly,

THEO. N. ELY, *General-Superintendent Motive-Power.*

The New York Central and Hudson River Railroad Company. Office Superintendent Motive-Power and Rolling Stock. Room 14, Grand Central Station.

WM. BUCHANAN, *Superintendent.*

NEW YORK, December 20, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In answer to your inquiry of 4th inst., we adopted the United States Standard form of thread three (3) years ago, and have never experienced any difficulty in maintaining the form of the threads, or in making nuts interchangeable.

For durability, think the Whitworth thread is the best, but for ordinary work, think this feature is offset by the difficulty in reproducing it.

The facility with which the straight threads can be produced by an ordinary workman with tools that can be readily made and maintained, so as to conform to the standard gauges, is a recommendation sufficient in itself.

Yours truly, WM. BUCHANAN.

New York, Lake Erie and Western Railroad Company. Office Superintendent of Motive-Power.

BUFFALO, N. Y., February 8, 1887.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In answer to yours of December 4th ult., making inquiry in regard to the Standard Screw-Thread recommended for general adoption by FRANKLIN INSTITUTE in 1864, in comparison with the Whitworth thread, would say that we have made careful inquiry in regard to this matter from all

our master mechanics and foremen of car-repair, and the general opinion is about as follows:

There is little question about the practical superiority of the Sellers, or United States Standard thread.

The principal differences between the two are in the angle of the thread and the form at top and root of thread.

The angle of the Sellers thread is more easily maintained than the other, because a templet can be accurately made without the use of special tools, as it is easy to construct the angle geometrically. It is also simpler and cheaper to cut the Sellers thread in a lathe. It is a difficult matter to make the nut fit closely on the curved portion of the Whitworth thread, and practically the bearing surface will probably be limited to the straight parts making it considerably less than in the Sellers system, consequently more liable to be distorted as far as this element goes.

We have no trouble arising from the wear of the United States Standard tap sufficient to prevent the nuts from being interchangeable.

Yours truly,

ROBERT SOULE, *Superintendent Motive-Power.* T.

The Pratt & Whitney Company, Manufacturers of Machinists' Tools.

HARTFORD, Conn., U. S. A., December 29, 1886.

DR. WM. H. WAHL, Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Your favor of the 28th inst., is to-day received. We trust you will pardon us for the delay in complying with your esteemed request of the 4th inst., mainly due to absence of the writer to whom the matter was referred, and subsequent unusual demands upon his time.

Regarding our experience as manufacturers of taps and dies, especially those covering the application of the Sellers System of Screw-Threads, now known as the FRANKLIN INSTITUTE or United States Standard, we can say, as stated in our letter in the *Railroad Gazette*, and published in their issue of September 24, 1886, included in article on "Screw-Threads," the orders we have received for taps and dies from railroad companies, bolt manufacturers, bridge builders and manufacturers generally, in the United States, are largely for the United States Standard thread. Fully ninety per cent. are strictly so, and many of the others not United States Standard in form of thread and pitch, are so in shape of the thread, *i. e.*, flat at top and bottom, one-eighth of the pitch, and having a greater number of threads per inch.

This is necessary for special cases, such as tool work and small diameter taps and bolts.

The form of the Sellers, FRANKLIN INSTITUTE or United States Standard thread, is such as to make it the most practicable for duplication to gauge, and by making the outside diameter slightly larger (not, however larger in the angle of the thread), the life of the tap or before it wears below gauge size, is greatly lengthened.

The claim that the form of the Sellers thread cannot be maintained in use, seems in our experience, inadmissible, for although the corners may wear slightly, this wear is unimportant if the taps are properly used, and

especially so, if made as recommended—slightly larger in the outside diameter.

Our position in the matter is stated more fully in the article published in the *Railroad Gazette*, referred to, and should you desire further information, or other than here given, we shall be only too glad to be of service to you if in our power.

May we retain the copies of the translation and the letter issued to the railway companies?

Regretting the delay, we are, Yours respectfully,

THE PRATT & WHITNEY COMPANY,

GEO. M. BOND, *Manager Gauge Department.*

[Following is the article from the *Railroad Gazette, September 24, 1886*, referred to in Mr. Bond's letter.]

SCREW-THREADS.

The last issue of *Engineering* publishes an article on "Screw-Threads," chiefly dealing with a movement, in Germany, to abandon the Whitworth Standard for a new one based on metric measures, in which some very large-sized and strangely erroneous statements are made in reference to what has now become the American Standard—the Sellers thread. It says:

"The form of cross-section Whitworth adopted for ordinary purposes, was that of a triangle, whose height was 0·96 pitch and the angle at the bottom of the threads 55°; one-sixth of these triangular sections was rounded off at the top and bottom. This system has been very widely and almost universally used for the last thirty years, the chief and only important exception to their universality being in the United States, where Sellers threads are very much used: they are of a slightly different pitch and form of cross-section, being an equilateral triangle with one-eighth of the depth cut off square, both top and bottom.

"The objection (to the form of the Whitworth thread) is totally unjustifiable, for thirty years of practice have most unmistakably proved the Whitworth form of cross-section to be the best; the square-tipped thread, on the other hand, as advocated by the metrical system, has proved unsuccessful. It has been thoroughly tried by Sellers in the United States, where it has been found practically impossible to produce a good thread by screwing apparatus, the sharp corners on the taps and dies rapidly break away, when a very imperfect thread must naturally follow. The present state of affairs in America conclusively shows the system to be a failure, and all the leading machine tool-makers there are supplying nothing but the **V**-shaped thread very similar to Whitworth's."

The Sellers threads are, indeed, "very much used," as they are the standards of the United States army and navy, and of the Master Mechanics' and Master Car-Builders' Associations, and of most of the large railroad shops at least. That "all" the leading tool-makers are supplying "nothing" but the **V**-thread "very similar to Whitworth's," is a fabrication, by some one, out of the whole cloth. The facts of the case are, that from eighty to ninety per cent. of the taps and dies sold by various dealers are already of the Sellers Standard, and the remainder of a plain **V**-thread, the latter having

been formerly universal, and being still quite largely in the majority, taking the whole United States together. That the Sellers Standard is, in any sense of the word, going out—and still less that it has practically gone out, as *Engineering* explicitly asserts—is utterly untrue. On the contrary, it is coming in. There is little room for doubt that its use is becoming more general every day, and it would now be hard to find a railroad anywhere on which it would not be asserted, at least, that the Sellers (or "M. C. B.," or "United States," as it is variously known) Standard was in use. Many more will assert that they use it than actually do use it, but that is natural.

The comparative merits of the Whitworth and Sellers Standards we are not discussing. This, however, we may say, that records, as respects durability and adherence to standard, are being made every day with taps and dies of the Sellers Standard, which certainly have not been, and probably cannot be, surpassed or even approached. The "sharp" angles (120°) do not, so far as we have ever heard, or can learn, give any difficulty from breaking off, while they do enable the standard to be exactly reproduced and readily maintained, so that complete interchangeability is assured. As it now appears quite certain that it will come into practically universal use in America, and as there is no prospect that any other standard will, anything calculated to impede its, so far, continuous progress to that end is greatly to be regretted. Fortunately, *Engineering's* assertions are so exaggerated, and—to anyone familiar with American practice, palpably false—that they are calculated to disprove themselves.

To make assurance doubly sure in this matter, we addressed an inquiry to the Pratt & Whitney Company, of Hartford, Conn., famous throughout this continent, and, we should imagine, throughout the world, not only for the magnitude and excellence of their products, but for their exertions and success in turning out minutely exact standards of various kinds, and especially for screw-threads. We risk little in saying that no house in the world is better qualified by experience to form correct conclusions in such a matter. The following is their reply:

"Referring to *Engineering's* comments on the second objection brought up by the commission and the Karlsruhe Society against the Whitworth thread, viz.:

"'(2.) The Whitworth system being measured in inches, it is inconvenient for metrical measurements.'

"We would say that if the writer had been aware of the fact that the British Board of Trade had established *in decimal sizes* all Birmingham gauge dimensions—in effect on and after March 1, 1884—he would not have made such a senseless assertion as is there given.

"'If a new universal system of screw-threads must be adopted, then it should not be tied down to any special system of measurement, but should rather be designed on a system of standard gauges of various grades, similar to our Birmingham wire-gauge system.'

"In regard to the disposal by *Engineering* of the third objection raised to the Whitworth thread by the Karlsruhe Society, viz., (that it is difficult of manufacture) a method of disposal, which has justly aroused your indigna-

tion and our own, we can also say that the Sellers or FRANKLIN INSTITUTE Thread, now generally known as the United States Standard, is, in every respect a more practical form of thread to maintain to gauge than the old **V**-thread, or even the Whitworth, and is a much more simple thread to produce by machinery or the ordinary work-shop tools than the latter form.

"As to the Sellers thread being 'a failure,' will only refer to the fact that in our large and increasing production of taps and dies for the market in this country, *ninety per cent.* are United States Standard, while many not strictly United States Standard in number of threads per inch, are so in form of thread, *i. e.*, one-eighth of the pitch flat, top and bottom.

"**V**-threads and over-size threads are *not* used to the extent they once were, thanks to the untiring devotion of the Master Car-Builders' Association, through their committee having this matter in charge; and it is now an accomplished fact that bolts and nuts are interchangeable throughout the United States, which previously was not possible with the old system of **V** and over-size threads.

"Furthermore, a United States Standard tap made in the proper manner will cut *ten times* as many nuts as will one simple **V**-thread, without appreciable change of size as compared with a standard gauge.

"The United States Standard form of thread embodies a condition which makes this great lengthening of the life of a tap possible, and this is not nearly so easily accomplished in the Whitworth thread. At all events, it is impracticable in the latter form to carry out the conditions referred to, and an impossibility in the **V**-thread.

"As to the objection regarding relative strength of the bolt cut with the United States Standard or the Whitworth thread, we can refer to the United States Navy Board report of May 9, 1868, which conclusively shows this objection to be unfounded. "THE PRATT & WHITNEY COMPANY.

("GEORGE M. BOND, *in charge of Gauge Department.*")

This is not the first time that facts and figures as to American practice have been "evolved from the inner consciousness" of writers across the water, to suit the occasion, but it is not often that such a complete perversion and reversal of the facts is given currency in a journal of standing. In addition to the railroad shops, the Baldwin Locomotive Works, and nearly, if not quite, all the other large locomotive shops, are using the Sellers system, as are also most of the car shops. Hoopes & Townsend, of Philadelphia, the largest single manufacturers of track bolts, are also using it. The prospects are excellent that the system will come into universal use, as it is now in large and rapidly increasing use. A correction would, therefore, seem to be in order.—*Railroad Gazette, Sept. 24, 1886.*

I have taken this method of replying to your inquiry as best calculated to answer the allegations made in (London) *Engineering*, of September 10, 1886, and have only to add, that, from the letters and publications above referred to, it must be evident that the Sellers or FRANKLIN INSTITUTE Standard for pitches and form of

thread is accepted and used throughout the United States, to the exclusion of any other; that is to say, while there are still some parties who have not adopted any standard, there are none who have adopted any other standard than the Sellers.

Hoping you may find the information herewith forwarded to be a satisfactory answer to your inquiries, I have the honor to remain, Yours respectfully,

WM. H. WAHL, *Secretary.*

BERLIN, W., den 19. Februar, 1887,
Wichmannstrasse 14.

Herrn WM. H. WAHL, *Secretär des* FRANKLIN INSTITUTE, *Philadelphia.*

SEHR GEEHRTER HERR:—Zu grossem Danke sind wir Ihnen verpflichtet für die grosse Mühwaltung, der Sie sich infolge unseres Gesuches vom 22. October, v. J, unterzogen haben, und für Ihre inhaltreiche Sendung vom 31. Januar, d. J., welche zugleich unser Frg. vom 14. dieses Monats erledigt. Wir sind dadurch in die Lage versetzt, unsere Bestrebungen für ein einheitliches Gewinde von Sellers'scher Querschnittsform auf den Vorgang in Ihrem Lande zu stützen und den falschen Darstellungen englischer Zeitschriften entgegenzutreten, welche der nationalen Eitelkeit wohl etwas mehr Rechnung tragen, als recht und billig ist.

Mit Freuden stellen wir Ihnen unsere Gegendienste zur Verfügung und zeichnen, Hochachtungsvoll,

DER VEREIN DEUTSCHER INGENIEURE,
Th. Peters.

[*Translation.*]

BERLIN, W., February 19, 1887.
Wichmann Street, 14.

WM. H. WAHL, *Secretary* FRANKLIN INSTITUTE, *Philadelphia.*

DEAR SIR:—We owe you many thanks for the painstaking manner in which you have attended to our request of October 22, 1886, and for your valued sending of thirty-first of January, 1887, which also answers ours of the fourteenth of February, 1887.

With the facts now in our possession we are enabled to support our efforts for the introduction of a standard thread, having the Sellers form of cross-section, upon the precedents established in your country, and to reply to the false representations of the English journals, which incline rather to the gratification of the national vanity than to what is right and proper in the premises. We gladly place ourselves at your disposal for a return of favors, and remain,

With high esteem,

THE SOCIETY OF GERMAN ENGINEERS,
Th. Peters.

RAINFALL AND WATER-SUPPLY.

By John Birkinbine.

[*A Lecture delivered before the* Franklin Institute, *Friday, February 4, 1887.*]

The Lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Ladies and Gentlemen:—The close relation, or rather, we might say, inseparable connection between rainfall and the procurement of a supply of water for public or domestic uses, while recognized in a general way, is far from being appreciated; and we are apt to forget that all available permanent water-supply is directly traceable to rainfall. Perhaps you will correct me, and advise the use of the terms "directly or indirectly," but we are probably justified in using the term "directly." Nature's laboratory is not a secret one; we can see, if we will, the methods which are employed to accomplish certain ends; and can notice the direct connection between rainfall and all water-supply. We admit that all visible streams or water-courses are immediately traceable to the rain which falls upon their respective drainage areas; and the many unseen or underground streams (the presence of which are determined by various methods which expose the formation of the earth), also owe their existence to certain territories upon which the rain is precipitated, and which are underlaid by certain stratifications of rock or to bodies of water which intercept these strata. The geological structure of a specific district, therefore, naturally affects the water-bearing strata and their position in relation to the surface; but it is generally the disturbed condition of the rocks which causes these subterranean waters to rest in basins or pools, or to find vent as springs. Although where the stratification is regular, and its seams or crevices are continuous, water is often obtained at great depths, apparently beyond the influence of rain, or, as far as can be determined from any connection with other reservoirs, the source from which this water comes, and that which maintains its flow, is the rainfall.

Whether as a gentle shower, or as silently-falling snow, or as a rain-storm, all precipitation of moisture has for its ultimate effect

the production of a proper proportion of water for the growth of vegetation and for the use of mankind, and the quantity of water represented by a given rain- or snow-fall, can be but imperfectly understood or appreciated. Calculations of the volume, weight and power necessary to elevate the water will astonish an investigator, and it is my desire to present, if possible, some conception of the force thus represented.

No attempt will be made to estimate the power which condenses and holds one volume of oxygen and two volumes of hydrogen into a volume $\frac{1}{1800}$ of the space which they fill as gases; for it is claimed that to reduce oxygen and hydrogen to the form of water a pressure of 40,000 pounds per square inch is required. And here we may refer to the fact that Faraday demonstrated that to decompose one drop of water required as much electricity as is contained in the thunderbolt. We will, however, consider the power which is apparently more within our comprehension; namely, that of vaporization, which, while not changing the compound of the two gases, transforms water [which is heavier than air] into vesicles or vapor which is carried to great heights above the earth, and wafted by winds for thousands of miles over the surface of the globe. When we remember that by far the greatest amount of evaporation is near the equator, and that the ocean is the reservoir from which the rains are produced, we may form some idea of the work done, but a very inadequate conception of the power employed.

The presence of water in the atmosphere, which as a great gaseous sea, forms an envelope surrounding the globe, is appreciable in so many ways, that it is remarkable this presence is so often forgotten by us. The dew on the blade of grass, the frost on the window, the brilliant colors of the rainbow, the fog on the ocean, the mist in the valley, the majesty of the cloud bank, the rain, the hail, the snow, all are constant evidences that we exist in an atmosphere in which water is always present in appreciable amount, the quantity of water varying with location, surroundings, temperature, etc. The general composition of the atmosphere is given in *Miller's Elements of Chemistry*, as follows:

	Volumes.
Oxygen,	20·61
Nitrogen,	77·95
Carbon dioxide,	0·04
Aqueous vapor (average),	1·40

It contains also traces of nitric acid, ammonia and carburetted hydrogen. The total weight of water in the atmosphere surrounding the earth is estimated to be 54,460,000,000,000 tons; a weight of which we can form no conception, much less realize how it can be held in suspension, as it were; for the air is a mixture and not a chemical compound, or a distinct substance like water. Prof. Cooke, of Harvard, says: "We may regard the globe as surrounded, by at least three separate atmospheres—one of oxygen one of nitrogen, and one of aqueous vapor—all existing simultaneously in the same space, yet each entirely distinct from the other two, and only very slightly influenced by their presence. Oxygen and nitrogen cannot be reduced to liquids even by the intense cold of the poles. The slightest reduction of temperature, however, when the air is saturated with moisture, is sufficient to condense a portion of the vapor to water and to shower it in drops of rain. On the other hand, when the temperature rises, the heat converts more water into vapor, and the aqueous atmosphere is replenished. Thus it is that the atmosphere of aqueous vapor on the earth is liable to very great fluctuations, from which the Creator has protected the great mass of the air by endowing oxygen and nitrogen with the power of retaining the aëriform condition under all circumstances, and the fluctuation in the one case is as important as the stability in the other." *

The presence of moisture in the air is made constantly manifest to the sense of sight, particularly by sudden changes of temperature; but often there are circumstances which attract attention where the conditions are in whole or in part produced by artificial means. A very marked instance of this was noticed in starting an iron works in New York State last winter, when the thermometer for a week seldom indicated a temperature above zero, and for days averaged — 10°. When doors were opened and the cold dry air rushed into rooms which were warm and moist, clouds of vapor were produced, which filled the apartment as with steam, and such in reality it was. In several instances snow was the result. To prevent freezing, the machinery was kept in motion in advance of the requirements, and the air from the blowing-engine was allowed to escape through a safety vent. When all was in

* *Religion and Chemistry*, p. 71.

readiness, it was found impossible to close this valve, owing to the ice, one inch in thickness, which had formed on it by the moisture in the air which passed through the blowing-engine, and came from a warm room, being condensed and congealed by the lower temperature of the outside air.

In Mr. Lorin Blodget's work on *Climatology*, he states that, "for much the larger area of the United States, and for all portions east of the Rocky Mountains, the distinguishing feature of the atmospheric precipitation in rain is its *symmetry and uniformity in amount over large areas.* The quantity has rarely or never any positive relation to the configuration of the surface, which would identify it with the distribution of Western Europe and the North Pacific Coast; and, in contrast with these, it has a diminished quantity at the greater altitudes generally, and the greatest amounts in the districts near the sea level. It also differs from these districts, and from large land areas generally, in having a greater amount in the interior than on the coasts for the same latitudes, at least as far north as the forty-second parallel of north latitude."*

We must not interpret this extract too literally, for they are generalizations and we cannot overlook many local influences which affect the rainfall. To a considerable extent, the position of the rain-gauge influences the quantity of precipitation measured, for series of careful records, taken at various localities, and covering considerable periods of time, indicate that the quantity entering the gauge, diminishes irregularly with its height above the ground; probably on account of the greater wind velocity at the higher level. One authority asserts that, at a height of twenty feet, this decrease amounts to as much as ten per cent. of the entire rainfall; and one exceptional case is recorded where the measured precipitation at an elevation of fifty feet, was but forty per cent. of that at the earth's surface. Our water department has attempted to construct a curve showing this decrease from its own observations, as well as from reported experiments; this curve demonstrates that at an elevation of forty feet above the ground eighty-seven per cent. of the actual rainfall enters the gauge. Commenting upon the question, why there is less rainfall caught in gauges high above the ground than in those on the ground, Prof. Cleveland Abbe, in his lecture in December last, upon "Popular Errors

* *Climatology of the United States*, p. 317.

in Meteorology,"* says: "There is really the same amount of rainfall at 100, or 50 feet altitude as on the ground; the fault is in our rain-gauge which is exposed to stronger winds when set high up, and to almost no wind when flush with the ground. The stronger winds deflected around the gauge carry the drops to one side, and hence the higher gauge catches less than the lower one."

The variations are prominently shown in the annual report of the Philadelphia Water Department for 1885, in which the average recorded precipitations for the years 1883, 1884 and 1885 are given as follows: (The percentages refer to the United States Signal Station as a standard.)

U. S. Signal Station,	37·25	inches,	percentage	100
Philadelphia Water Department,	35·29	"	"	95
Pennsylvania Hospital,	42·72	"	"	115
Germantown,	41·25	"	"	111
West Chester,	50·59	"	"	136
Pottstown,	44·52	"	"	119
Reading,	42·91	"	"	115

There are other localities mentioned in the report, but I have selected those which are nearest to the city, and we will consider only the first three, which are within the limits of the city, and are taken where it is presumed all possible precautions against error are provided for. These three show a variation in the average, for the three years, of 6·43 inches of rain, and, if we select monthly records, the differences are even greater than the average, as the following will demonstrate: In August, 1885, the U. S. Signal Station reported 6·80 inches, the Water Department 7·90, and the Pennsylvania Hospital 10·08 inches, a difference between extremes of 3·28 inches. In the months where the rainfall is not so heavy as in August, the differences are scarcely less marked. Thus, the following are recorded:

	U. S. S. S.	*W. Dept.*	*P. Hospital.*				
November, 1884,	2·31	2·98	4·01,	a difference	of	1·70	inches.
In October, 1885,	3·33	3·67	4·85,	"	"	1·52	"
In December, 1884,	3·28	3·78	4·76,	"	"	1·48	"

It is not my purpose to take up the subject of rainfall generally, although the topic for the lecture might possibly have given

* See this JOURNAL, **123**, 115.

rise to such expectation. The purpose of the lecture would be better expressed by the more prolix title, "The Water which Falls upon and which is Required by the City of Philadelphia"; and we will now consider the first branch of the subject, which was suggested by the favor with which an article,* entitled "Sun Pumping," prepared for one of our technical journals, was received.

THE WATER WHICH FALLS UPON PHILADELPHIA.

Have you ever thought of the volume, or the weight of the water which is annually precipitated upon the area covered by the city in which we live; or even upon the quantity which falls upon a square mile or a square acre? If not, the amount will be a surprise, and, at the risk of appearing to treat the subject in an elementary manner, I will ask you to follow some calculations which will possibly give an idea of the volume of water, most of which the sewerage system of a great city must care for, the work done by the sun in elevating the weight to the cloud-level (if such a term is admissible), and the relation that the rain falling upon the city bears to the water supplied to it. Let us first consider the precipitation upon an acre and a square mile:

In a square acre there are . . . . 43,560 square feet.
" " mile " $(5,280 \times 5,280) = 27,878,400$ " "

Therefore, each foot of rain which falls upon these areas is equivalent in volume to—

43,560 cubic feet, or 325,829 gallons of water per acre; and
27,878,400 " " " 208,530,432 " " " " square mile.

Now, in round numbers, thirty-two cubic feet of water, under ordinary conditions and temperature, weigh one net ton (2,000 pounds), and thirty-six cubic feet weigh one gross ton (2,240 pounds). On this basis, the weight of water can be readily calculated; however, as the usual method of reporting the rainfall is in inches and not in feet, we may first bring the above figures to this base.

For each inch in depth of rain, the figures per acre and per square mile are as follows:

	Volume.	Weight.
Per acre,	3,630 cubic feet, or 27,152 gallons =	100·8 gross tons. [113·4 net tons]
Per sq. mile,	2,323,200 cu. ft., or 17,377,536 gals. =	64,533⅓ gross tons. [72,600 net tons.]

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* *Iron Age.*

On the authority of Chief Engineer and Surveyor Mr. S L. Smedley, the entire area covered by the city, is $129\frac{383}{1000}$ square miles, and if we multiply the volume and weight of water per square mile representing one inch of rainfall, by the area of the city, we have the following :

Volume.

300,582,586 cubic feet, or 2,248,357,740 gallons.

Weight.

8,349,516 gross tons, or 9,393,206 net tons.

This weight is only appreciable by comparing it with the quantities of materials with which we are familiar. During the year 1886, the anthracite coal district of Pennsylvania produced over 33,000,000 gross tons, a larger output than ever before; and, as far as the product is concerned the year was also the greatest in iron production, viz., 5,684,543 gross tons. But four inches of rain on the area within the corporate limits of the city of Philadelphia, weigh as much as all of the anthracite coal mined last year in this state ; and one inch of rain upon this area represents a weight nearly fifty per cent. greater than the total output of pig iron in the United States in 1886. The wheat crop of the United States for 1886, estimated by the Department of Agriculture at Washington at 457,000,000 bushels, weighs about the same as one and one-quarter inches of rain on the area of this city.

From the table of the means and extremes of rainfall, as observed at the Pennsylvania Hospital, we find that the annual average for fifty-seven years was 45·19 inches, or 3·766 feet.

TABLE OF THE MEANS AND EXTREMES OF RAINFALL AT THE PENNSYLVANIA HOSPITAL, PHILADELPHIA, COMPILED FROM THE RECORDS FROM 1830 TO 1886, BOTH YEARS INCLUDED.

	Average Rainfall in Inches.	*Maximum Rainfall in Inches.*	*Minimum Rainfall in Inches.*
January, ...	3·577	7·837	0·730
February, ...	3·160	6·615	0·551
March, ...	3·551	6·985	1·087
April, ...	3·524	7·750	0·585
May, ...	4·031	8·685	1·070
June, ...	4·142	11·025	0·887
July, ...	4·177	11·805	0·985
August, ...	4·729	15·816	0·620
September, ...	3·645	13·904	0·249

	Average Rainfall in Inches.	Maximum Rainfall in Inches.	Minimum Rainfall in Inches.
October,	3·324	10·050	0·447
November,	3·566	9·025	1·036
December,	3·764	7·378	1·044
Winter,	10·500	15·370	4·711
Spring,	11·167	17·650	6·594
Summer,	13·047	29·228	6·256
Autumn,	10·526	18·011	3·359
Year,	45·190	61·135 (1867)	33·240 (1834)

We can now estimate the weight and volume of the average amount of rain which annually falls on the city, as follows:

Volume.

For the year, 13,580,327,043 cubic feet, or 101,603,286,282 gallons.

Weight.

377,314,640 gross tons, or 424,478,970 net tons.

In *Stahl und Eisen*, Prof. Ehrenwerth estimates that the total annual coal production of the world approximates 400,000,000 tons (metric).

Therefore, if we accept Prof. Ehrenwerth's figures as correct, the rain, which has fallen annually on the area of Philadelphia, has averaged over ninety-five per cent. of the total coal output, at present, of the world.

Upon the assumption of a uniform distribution of the precipitation throughout the year (a condition which the table shows, and which we know, does not exist), the daily average for the fifty-seven years under consideration, would be:

Volume.

37,214,595 cubic feet, or 278,365,171 gallons.

Weight.

1,033,739 gross tons, or 1,162,956 net tons.

But the table demonstrates that in the year 1867 as much as 61·135 inches of rain fell, which would increase the above amounts over thirty-five per cent., and that in the year 1834 but 33·24 inches of rain are reported, which is about seventy-three per cent. of the average precipitation, and the figures, as above, for that year would be but seventy-three per cent. of those given. It will be noted that the average rainfall occupies a point very nearly midway between the two extremes above given; this mean between the extremes is 47·188 inches.

Similarly the maximum and minimum monthly precipita ions

indicate variations from these figures, but, for the present, we will consider only the minimum monthly rainfall to estimate a possible daily average from it, leaving the maximum to actually recorded severe rain-storms; for the rainfall has ranged from *nil* to 7·323 inches in a day. Taking the minimum monthly rainfall from the table, viz., September, 0·249 inches, the daily average on the assumption of uniform distribution throughout the month is 0·0083 inches, which indicates that for any one month the minimum amount of water falling per day on the city of Philadelphia was:

Volume.

2,494,835 cubic feet, or 18,661,369 gallons.

Weight.

69,301 gross tons, or 77,963·5 net tons.

(or probably less than the evaporation from the area of the city in the same time.)

To consider the maximum rainfall, we look up the records of severe rain-storms, and by reference to the Pennsylvania Hospital reports, we find that from and including the year 1840, there were twenty-seven days on which over three inches of rain fell. The greatest amount being 7·323 inches, which are reported as falling during the twenty-four hours in August, 1873; the next in August, 1867, with a record of 6·680 inches, and in August, 1860, 6·005 inches. On two consecutive days (the 22d and 23d) of September, 1882, 5·566 and 4·260 inches, respectively, fell, a total for the two days of 9·826 inches. Of the twenty-seven days, on which over three inches of rain fell, eleven were in August, four in June, three in October and September, two in April and November, and one each in January and July; the heaviest of these last two being a fall of four inches in January, 1875.

Most of the large precipitations above mentioned, continued but for a portion of a day; in fact, many of the records mentioned are for precipitations lasting but part of a day. Some of these will be noted later.

If, for the purpose of forming an appreciation of the enormous quantity of water represented by one of these heavy down-pours, we take the latest recorded one for a day, viz., August 4, 1885, 4·46 inches, we find that it was equivalent (for the area of Philadelphia) to a

Volume

of 1,340,598,334 cubic feet, or 10,027,675,520 gallons, and

Weight

of 37,238,843 gross tons, or 41,893,698 net tons.

Or, to make the amount appreciable, such a storm as that mentioned, when less than four and one-half inches of rain fell in a day, deposited on the area of Philadelphia, a weight of water greater by over twelve per cent. than the total amount of anthracite coal mined in 1886; and this weight of water represented more than half of the weight of the total crop in 1886 of corn, wheat and oats.

The volume would be over one-fourth of that of the great storage dam proposed for the Croton Aqueduct at Quaker Bridge, to cost the City of New York, $7,000,000.

The automatic recording water-gauge, connected with the office of the Water Department, at Thirteenth and Spring Garden Streets, shows that on the morning of November 18th last, 0·52 inches of rain fell in nine minutes; and a similar gauge, located at Doylestown, indicated, on August 3, 1885, a fall of one and one-half inches of rain in twenty minutes. It is unnecessary to follow calculations further to form a conception of the amount of water represented by such precipitation; but it will be interesting to note that a rainfall, over the area of Philadelphia, such as that recorded last November, is equivalent to a flow of 290,000 cubic feet per second; which is 15,000 feet per second more than the reported average flow of water over the falls of Niagara.

If time permitted, we could follow the subject of the weight and volume of water which falls upon nearly 2,000 square miles of drainage area of the Schuylkill River, of which but about forty per cent. passes Fairmount Dam, giving an average daily flow for the river, at ordinary stages, of less than three times the average daily precipitation on the area of Philadelphia above determined.

It has been the desire to draw our minds to an appreciation of quantity and weight, and I would now ask that you follow me to a conception of the *power* represented by the rainfall upon the area of our city, or, if I may use the term the "Horse-power employed in Sun Pumping," for as Guyot says, in *Earth and Man:* * * * "The Sun, the great awakener of life, the king of Nature, shoots his burning rays every day athwart the waters. He causes the invisible vapors to rise, which, lighter than the air itself, unceasingly tend to soar into the atmosphere, filling it, and constituting within it another atmosphere. In their ascending movement, they encounter the colder layers of the higher regions of the atmos-

phere, which perform the part of coolers. They are condensed in vesicles, that become visible under the form of clouds and fogs. Then borne along by the winds whether invisible still, or in the state of clouds, they spread themselves over the continents and fall in abundant rains upon the ground which they fertilize. * * * To study the distribution of the rains and of the moisture on the surface of the globe, is to study the course of the winds which are their carriers "*

The power that is required to convert the water into vapor and lift it far above us, can be but imperfectly understood ; but to form a conception, let us consider merely the elevation of the water to the cloud level. Prof. Loomis, in his text book on *Meteorology*, gives the average height of the clouds as two miles ; we know that some of the clouds which drop their rain upon the earth are much lower than this, but we do not know how high the water was raised, nor how far it was carried before intercepted by the cooler stratum that made the vapor visible as cloud. Let us then assume the average height to which the water, (which as rain falls on Philadelphia) is elevated, to be 10,000 feet ; and, using the figures with which we have become somewhat familiar, attempt to estimate this power. If our estimate of height is excessive, it is capable of reduction by the decimal system to any amount required.

Hann is given as the authority for the statement that five-tenths of the aqueous vapor is found within the stratum between the sea level and 6,500 feet above it, and that nine-tenths of the vapor is below 20,000 feet. It is asserted that from a series of balloon and mountain observations, he formulated the following general table :

Altitude above Sea Level.	*Proportionate Quantity of Aqueous Vapor.*
1,000 feet,	1·00
2,000 "	0·87
3,000 "	0·73
4,000 "	0·64
5,000 "	0·56
6,000 "	0·56
7,000 "	0·48
8,000 "	0·42
10,000 "	0·34
12,000 "	0·27
14,000 "	0·23
16,000 "	0·18
18,000 "	0·16
20,000 "	0·13
22,000 "	0·07

* *Earth and Man*, p. 130.

This is referred to, that you may note a possible error in the assumption, but as we know that many of the lower strata of clouds are evanescent, and are dissipated by the sun's rays, while most of our rains come from clouds at a greater elevation, we will make the estimates on the assumption that all of the vapor which falls as rain has been raised to an average height of 10,000 feet; for the object of these estimates is rather to form a conception of these forces of nature, than to give absolutely exact figures.

To make the estimates of power, let us use the familiar standard of 33,000 pounds raised one foot high per minute as one horse-power, and apply the formula:

$$\frac{\text{Net tons per day} \times 2{,}000 \text{ lbs.} \times 10{,}000 \text{ feet}}{33{,}000 \text{ foot-pounds} \times 1{,}440 \text{ minutes}}$$ equals the HP. developed.

It is only the developed horse-power which we shall consider, and no allowances will be made for losses of any kind.

We, therefore, have the following figures to represent the horse-power to be developed in raising to a height of 10,000 feet the quantities of water represented by the precipitation of—

	Horse-power.
One inch of rain on one acre,	47·7
" " " " " " square mile,	30,555
" " " " " 129·383 square miles (the area of Philadelphia),	3,953,370
The average daily precipitation of the month of minimum rainfall (0·249 inches) on the area of Philadelphia,	32,812·9
The average daily rainfall, calculated from the annual average (45·19 inches) on the area of Philadelphia,	489,460
The maximum rainfall recorded in twenty-four hours in fifty-seven years (7·323 inches) on the area of Philadelphia,	28,950,524

To understand what these powers represent, we can best refer to the volume of the last census on manufactures, in which the total amount of steam- and water-power employed in 85,923 establishments reporting was 3,410,837 horse-power, of which 2,185,458 horse-power was steam-power, and 1,225,379 horse-power was water power. Therefore, if the census returns are considered to represent developed power, the entire manufacturing industry of the United States, as given by the census returns, has not sufficient

power connected with it, to raise in one day the water represented by one inch of rain on the area of Philadelphia and the entire steam- and water-power, as reported in the census, could not, in working together for twenty-four hours, develop more than twelve per cent. of what we have estimated as necessary to raise the 7·323 inches of rain which fell in one day over the area of Philadelphia to a height of 10,000 feet. To form an idea of the "sun-pumping" represented by a severe rain, such as above mentioned, when 0·52 inches of rain fell in nine minutes; we find that to raise an equal amount in the same time to a height of 10,000 feet would require the development of 329,000,000 horse-power. Now, if we apply Fairbairn's formula of "one cubic foot falling twelve feet per second equal to one horse-power" to Niagara Falls, where 275,000 cubic feet per second fall 230 feet, we find that the entire power which this immense cataract could produce in nine hours, would be scarcely sufficient to elevate to cloud-level the water which fell in the city of Philadelphia in the nine minutes above mentioned. In these general estimates, no allowances of any kind are made. I would offer one more comparison; at the western extreme of Lake Superior, close to the City of Duluth, the St. Louis River, a stream about double the volume of the Schuylkill River, falls in a distance equal to that from Manayunk to the Fairmount dam, from a height 100 feet higher than the Roxborough hill to tide level. And yet, upon the basis of one cubic foot falling twelve feet per second, this magnificent, but as yet undeveloped stream would supply but one-fourth the power to raise the average daily rainfall on the area of the city.

We can form another idea as to what the rainfall upon the area of the city of Philadelphia amounts to, which will probably be even more satisfactory than the calculations as to horse-power. The usual method of rating pumping-engines, is by the duty in pounds of water raised one foot high by the consumption of 100 pounds of coal; and although some tests have shown duties in excess of 100,000,000 foot-pounds, we shall consider that a sufficiently high basis for estimation, for it is much above the average work performed by the pumping-engines in the United States. If, therefore, we assume a duty of 100,000,000 foot-pounds, we will have for each gross ton of coal consumed 2,240,000,000 pounds of water raised one foot high. To elevate the water, (which fell as rain,) to

the cloud-level, say 10,000 feet, the following amounts of coal would be consumed:

	Gross Tons.
One inch of rain on one acre, ...	1·008
" " " " " one square mile, ...	645·33
" " " " " area of Philadelphia, ...	83,495·
45·19 inches of rainfall on the area of Philadelphia (that is, the average for fifty-seven years), ...	3,773,146·

That is, to raise the average amount of water, which has fallen annually upon the areas of the city of Philadelphia for the past fifty-seven years, would require the yearly consumption of 11·4 per cent. of all the anthracite coal mined in 1886, using the most improved pumping machinery.

Or, on the assumption of the same rainfall in the anthracite region as at Philadelphia, one-half of the total production of coal at the present mine development, would be consumed in raising the water, which falls as rain upon the 470 square miles of the anthracite region.

I recognize that in all of the calculations presented, there are many possible sources of error, and would therefore again remind you that they are intended as comparative and not as absolute estimates; their object being solely to present a conception, imperfect though it be, of the forces which are continually at work about us.

THE WATER WHICH IS SUPPLIED TO PHILADELPHIA.

No subject is of greater interest to each of us than the character and quantity of our water-supply, for on these depend largely our comfort, safety and health. It is not essential that we should enlarge upon this, nor will I consider it necessary at the present time to refer to the chemical analyses which have from time to time been published. That it is not all that we desire, is too well recognized to need mention; the presence of mud discoloring it, or the shortage in certain districts when heavy demands for fires, etc., have been made, are convincing proofs that an improvement is necessary; but that it is as unsatisfactory as some have asserted need, on the other hand, scarcely be noticed. However, a subject of so much importance cannot be too thoroughly discussed; but while we should look at it in all candor for the weak points, we should be equally frank in admitting the merits of the supply

upon which we depend. Those of our citizens, whose business calls them to various parts of our own country, or to foreign lands, and who have opportunities for observing the peculiarities of their own and foreign cities, cannot but agree that an absence of local pride seems to be pre-eminent among our citizens, and that we seldom or never "put our best foot forward." We are too apt to display our disadvantages, and to make light of our advantages, and in no one thing is this more pronounced than in some of the statements concerning our water-supply, which have obtained publicity. Several years ago, our deficiencies in this line were heralded throughout the country to our disadvantage, until, as one, familiar with water-supplies, facetiously remarked: "We were drinking poison, and our pipes had so *shrunk* in diameter that the supply was both unhealthy and inefficient." That the case is not as bad as this is evident from the fact that, although the year just past was one of unusually large water consumption, and that during the season of the greatest demand, there was a severe drought, few complaints of either the quality or quantity of water were heard. It is not my desire to be understood as asserting that we should not have a better water supply; on the contrary, it should command the most earnest and immediate attention of our city authorities; but the wholesale condemnation of what we now have, and the dire predictions as to the future which are published, are beyond the truth, and some of them are apparently instigated in the interest of special schemes.

Familiarity with the Schuylkill and Delaware Rivers, from which our supply of water is obtained, encourages one to appreciate their disadvantages; but the knowledge of their drainage areas, gained by tracing many of the various tributaries from their sources to their confluences with the rivers, and an intimate acquaintance with the industrial development of the region, permit me also to recognize their merits. No more reliable source of water-supply is obtainable than from a stream of considerable size, particularly if the water passes over rapids, or by falling over dams, etc., is exposed to aëration. But the otherwise available character of river water may, and in our case is, offset by deleterious drainage. This is particularly true of the Schuylkill River, from which over ninety per cent. of our supply is obtained; but some of the deleterious drainage which enters into it, fortunately for us, neutralizes other objectionable features.

Without entering into details of the drainage of the Schuylkill River, we may follow it from its source, in the anthracite coal regions, where it becomes so strongly impregnated with acid from the mines as to interfere with the life of fish, etc.; but this same acid destroys the organic matter emanating from a populous district probably as far as Reading. In the neighborhood of Reading, large tributaries draining a limestone formation enter the river, and so neutralize this acid that at Pottstown, forty miles above Philadelphia, the water which is supplied to that city from the river is comparatively unobjectionable. Below this point, Phœnixville, Norristown and Conshohocken likewise, obtain their water supply from the river; but they also add to its impurities a considerable amount, which would be greater still had they efficient sewage systems. The discoloration of the Schuylkill water (outside of the mill refuse, which could and should be largely prevented), comes principally from the streams which enter the river between Norristown and Pottstown, and which, while objectionable, is not positively injurious. The large volume of purer water brought to the river from tributaries below Norristown, and possibly the limestone streams in that vicinity, have a marked effect in the improvement of our water-supply as to potability. Our present water-supply is objectionable more from its mechanical than from its chemical impurities, and with proper methods for the prevention of objectionable matters entering the river, with ample settling capacity provided, with possibly aëration by mechanical means, our water-supply will continue to be above the average of that furnished to large cities. To-day, there is much that is objectionable to our senses, as well as to investigation, which can be removed. But as the city grows, the surrounding country will be more densely populated; the pollution of the stream being increased by the augmented population and industries, and it is probable that it would be much cheaper to construct a system of supply obtained from sources which can be more readily controlled from contamination, than to attempt to maintain the purity of the river in the distant future. It is here that a study of the rainfall is essential to the determination of a suitable water-supply, and it will be necessary in providing for the future to select a source whose purity can be maintained, or to adopt a system which will prevent objectionable products from entering the water which is furnished to our citizens.

Those who heard, or who have read, the lecture delivered in this room by Dr. Leeds, will remember that he laid great stress upon aëration of the water supplied to cities, and recommended the use of air-compressors to deliver the air under pressure so as to take advantage of the solubility of oxygen.

He instances results which apparently sustain the statements as to the value of such oxidation, and the advantages of introducing the air under pressure, but if we admit all that is claimed, it is hardly probable that the method can be generally employed, particularly in works already established. He gives as a reason for the compressors which were purchased for the purpose, not being employed at our various Philadelphia pumping-stations, that "At only one of them, * * * has the process been applied, namely, at Belmont, the other mains being too leaky to permit of its being used." It would rather seem that the contours, followed by the lines of pumping-mains from the other works, were of necessity such as would not keep them free from traps in which the air can accumulate, and thus produce jars to destroy the pipes. One of the first rules of good pipe-laying is, wherever possible, to obviate air-traps, and the efforts of an engineer are to prevent the accumulation of air in the pipes, after they are laid. We can, therefore, not expect that with our water-supply as at present arranged, aëration, by means of compressors in connection with the pumping mains will be successful, their use would rather be attended with considerable risk to the pipe system. If the beneficial results from aëration can be maintained, and they are sufficient to command attention if but a portion of the organic matter is thus oxidized, it would appear that better and less risky methods of reaching the desired results would lie—

(1.) In the direction of raising the water above the surface of the reservoirs, and allowing it to fall in cascades, thus exposing it to the air, and, at the same time, adding ornaments to the reservoirs.

(2.) The idle compressors could be utilized by placing them near to, or upon, floats in the reservoirs and forcing the air under pressure into the water near the bottom; or,

(3.) As the lift would be but a few feet, rotary pumps, similar to wrecking pumps, could be placed on floats and large volumes of

water be quickly raised so as to fall in thin cascades and permit of aëration.

Either of these suggestions would appear to be applicable to our existing system of water-supply, and free from the serious objection of air in the pipe system; the disturbance of the water might, however, interfere with the settlement of matter held in suspension; but as our reservoir capacity is insufficient to accomplish any real clarification, of which we have evidence to-day in the color of the water, this would at present be a minor objection. For large storage reservoirs, in which the development of organisms cause unpleasant tastes, or odors, these methods may also be found efficacious.

The total amount of water supplied to the city of Philadelphia in the year 1885, as given in the published report of the Water Department, was 25,165,020,072 gallons, a daily average of 68,945,260 gallons. This amount was raised to an average elevation of 156·2 feet, and the work done was therefore 89,746,351,338 foot-pounds per day; or, on the assumption of continuous work, 62,323,855 foot-pounds per minute, equal to 1,889 horse-power continuously exerted.

Mr. John L. Ogden, Chief Engineer of the Water Department, states that, during the year 1886, the minimum daily pumpage was 49,187,598 gallons, and the maximum 102,202,857 gallons, the average being 78,432,289 gallons per day. If the average height to which this was pumped, was the same as in 1885, the increase would be 13·8 per cent., requiring the continuous development throughout the year of 2,150 horse-power.

Our calculations show that the average precipitation on the area of Philadelphia was equal to a volume of 278,365,171 gallons daily, or about four times the average daily pumpage of last year. Therefore, if we could collect twenty-eight per cent. of the water falling on the area of the city and store it, we would have an ample supply for our present requirements. But the collection of water, without storage, would not avail us, for we must provide for dry seasons, such as that which occurred last year, when from August 8th to October 26th, inclusive (eighty days), the Water Department gauge showed that but 1·578 inches of rain fell, which is equivalent to a deposition on the area of the city of 44,348,856 gallons per day, or fifty-six and one-half per cent. of the average

daily pumpage for the year, and probably less than the evaporation for eighty days.

The problem to be solved by our city authorities in securing a source of future water-supply, is fortunately not a difficult one, for there are several available drainage areas from which a supply of potable water can be obtained; either of which are more than ample for the present requirements of the city. The problem is, rather, how far into the future shall we look, and for how much of posterity shall provision be made? Upon the solution of this will depend also the character of the works constructed, and their number.

The available sources are:

(1.) The Schuylkill River, from which the water must be raised into the reservoirs by pumping, with the attendant constant expense of operating the machinery. To continue the use of this source, persistent precautions against pollution must be taken and provision for storage must be made.

(2.) The Delaware River, by pumping from a point or points away from the influence of the city's sewage. This will require the continual expense of maintaining machinery, increased storage' and demand watchfulness against future pollution.

(3.) Gravity supplies from one or more of the tributaries of the Schuylkill or Delaware Rivers, or from the upper waters of the latter stream. Such supply will be dependent upon the rainfall upon the areas drained, the percentage of the precipitation lost by evaporation, infiltration and absorption, and the storage capacity provided. While gravity supplies are generally more costly to construct than pumping works, they are less expensive to maintain, and the territory drained can be more readily controlled.

(4.) Publicity has been given to a project (which will probably never mature) to construct an immense dam across the valley of the Schuylkill, above Manayunk, to act in the double capacity of a store reservoir for a supply of water, and for power. This plan would remove much of the objectionable drainage, by *wiping out of existence* a large proportion of the manufacturing industries, and a considerable part of the town-sites along the river; and bring close to us the possible risk of the failure of the dam. If the damage to industries, to private dwellings, the losses to business centring about the city, and the changes of railroad lines which

this necessitates, are considered in connection with the fact that much of the objectionable drainage would still exist, it will hardly meet popular favor.

When the arrangements for this lecture were made, it was expected that the recommendations of the Chief Engineer of the Water Department as to a future water-supply would have been made public. Such, however, is not the case, but I understand that they will shortly appear and it would be discourteous to anticipate these recommendations; for those to whom have been entrusted the duty of determining what is best to be done, are entitled to a careful consideration on our part of the problems which they have studied out with so much care. But having from boyhood taken a lively and continuous interest in the water-supply of our city, I will be pardoned for expressing the conviction, based upon a careful study of the subject, that Philadelphia will obtain the best and most reliable water-supply by gravitation from one or more of the tributaries of the Schuylkill and Delaware Rivers, and in view of possible social or political disturbances, it would appear that for the future, a supply which did not make the city dependent on one source only would be advisable. To have a proper control of the areas drained, they should be the property of the city, and such purchase would, in view of the rapid reduction of our forest area, be likely to prove a profitable investment. Much of the area drained by these tributaries is imperfectly adapted for agriculture, but, if properly cared for, could sustain valuable forests, which would assist in securing the collection of the water falling as rain, by making the springs perennial, and at the same time grow timber of value. Philadelphia should not only control her water-supply, but also the sources from which it is obtained. A great city maintaining a magnificent forest preserve, wherein tree culture could be carried on both practically and technically, having the double purpose of maintaining the purity of the water-supply and the growth of timber for profit would do much to popularize a much neglected feature of state and national administration.

For whatever knowledge I may possess concerning the present or the future water-supply of the city, I am indebted to him, to whom I also owe the credit of any educational facilities or personal advantages, and it was in assisting my father in the study of the requirements of the city, that my interest in the subject originated.

It is, therefore, a great gratification to find that the results of the examinations, surveys and estimates, made at a large outlay during late years, are so close to those made by him twenty years ago, at an expense of about $5,000. I regret that his life was not spared to allow him to appreciate this, or to have others recognize the fact that his conception of what Philadelphia needed, was but a quarter of a century ahead of what the city must now have.

You may properly credit these statements to loyalty to the memory of my father, and I am proud to admit such fealty as influencing me. But I will ask those of you who may be interested in the subject to compare the results of reconnoisances on foot of the streams convenient to the city, the surveys, calculations and estimates published by him in 1865,* with similar data published as the results of examinations made, at a cost of $80,000, with the most approved instruments, with the help of a large corps of assistants, and with the advantage of twenty years of progress to confirm the above statement.

Either of the subjects embraced in the topic of this lecture are sufficient for an entire evening, and they have been but imperfectly treated. But if the data presented will assist us to recognize how immensely beyond our conception are the forces of Nature, which are constantly about us, if what has been said helps any one to appreciate the omnipotence of the Creator, at whose bidding "there went up a mist from the earth and watered the whole face of the ground," if any thought expressed may aid in securing for Philadelphia of to-day, and the Philadelphia of the future, such a water-supply as a great city deserves; or if any suggestion made will assist in securing your support to any honest endeavor to advance our city, your patience in listening to me will have been rewarded.

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* *Report upon Future Water-Supply of Philadelphia.* By Henry P. M. Birkinbine, Chief Engineer, 1865.

THERMODYNAMICS.

By Prof. De Volson Wood.

(*Continued from page 209.*)

We next consider the article on intrinsic energy, being article 247 of *The Steam Engine*, by Rankine. The intrinsic energy of a substance is the external work which it is capable of doing in being expanded from a given state as to temperature and volume (or pressure and volume) to that of total privation of heat and indefinite expansion. Since indefinite expansion is impossible in an actual machine, the quantity is *ideal*, but its value may be com-

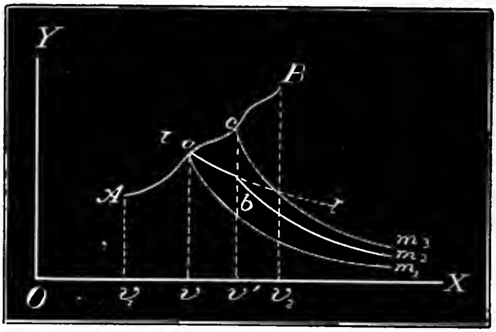

Fig. 3.

puted for the ideally perfect gas, and the algebraic form of an expression for its value be found for imperfect fluids.

It will be necessary, in the first case, to find an expression for the heat absorbed during a change of temperature, as well as of pressure and volume. In our preceding articles, explaining article 241, we found that the expression $\tau \frac{dp}{d\tau} dv$ was a measure of the heat absorbed for an expansion in which the temperature, τ, was constant; but this is only one condition out of an infinite number which may occur in practice. Suppose that heat be absorbed, so that during expansion the relation between the pressure and volume may be represented by the line $A\ B$, *Fig. 3*; it is required to find a differential expression for the amount of heat absorbed in passing from a to c, when a and c are consecutive points. To find

it, we proceed on the same principle that is used in many cases in geometry—inscribe a polygon, whose properties are known—and pass to the limit. Beginning at a, draw an isothermal $a\tau$, and through c the vertical $c\,v'$, intersecting $a\tau$ in b; so that, at first, the passage from a to c is along the isothermal $a\,b$ and the vertical $b\,c$. The abscissa of b in reference to a will be $v\,v' = d\,v$. Through a, b and c pass the adiabatics $a\,m_1$, $b\,m_2$, $c\,m_3$, conceived to be extended indefinitely to the right; then will

$$\text{area } m_1\,a\,b\,m_2 = \tau\,\frac{d\,p}{d\,\tau}\,d\,v.$$

The area $m_2\,b\,c\,m_3$ represents the heat absorbed while increasing the temperature at the constant volume v', the pressure being increased an amount $b\,c$. In this case, the temperature will be increased an indefinitely small amount, represented by $d\,\tau$. The determination of the heat necessary to increase the temperature by one unit (say 1° F), depends upon an experiment and a calculation, the process of which we will assume is known by the reader; the result of which is called the *specific heat at constant volume.* If the specific heat is constantly varying, it is only necessary to consider its *rate* at b; that is, it will be such a quantity as would increase the temperature 1°, if the specific heat of the substance remained uniform throughout the degree.

Let $K_{v'}$ = the specific heat of the substance at the state b, measured in foot-pounds; then will $K_{v'}\,d\,\tau$ be the heat necessary to raise the temperature from that at b to that at c, and

$$\text{area } m_2\,b\,c\,m_3 = K_{v'}\,d\,\tau.$$

Ultimately, when a and c are consecutive, the area $a\,b\,c$ vanishes and we have, if $d\,H$ be the heat absorbed in passing from a to c

$$d\,H = \text{area } m_1\,a\,c\,m_3 = K_v\,d\,\tau + \tau\,\frac{d\,p}{d\,\tau}\,d\,v \qquad (1)$$

which is, substantially, Rankine's equation (2), page 310; and is precisely the form given by Clausius for homogeneous bodies.

If, however, the substance is capable of an indefinite expansion, and if the aggregation of the substance does not change during such expansion, and if by an isothermal expansion the substance approximates more and more nearly to a perfect gas, as assumed by Rankine, then may the value of K_v be transformed as follows:

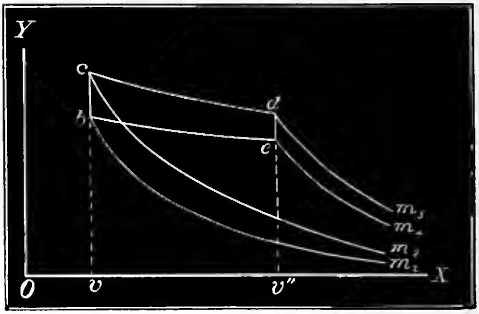

FIG. 4.

We have already found, *Fig. 4*,

$$m_2 b e m_4 = \tau \int_{v}^{v''} \frac{dp}{d\tau} dv,$$

$$m_2 b c m_3 = K_v \, d\tau.$$

Similarly

$$m_4 e d m_5 = K_{v''} \, d\tau$$

$$m_3 c d m_5 = (\tau + d\tau) \int_{v}^{v''} \frac{d(p + dp)}{d\tau} \, dv$$

$$= \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2 p}{d\tau^2} dv \, d\tau + d\tau \int \frac{dp}{d\tau} dv + d\tau \int \frac{d^2 p}{d\tau^2} dv \, d\tau$$

$$= \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2 p}{d\tau^2} dv \, d\tau + \int dp \, dv,$$

the last term of the preceding expression being omitted, it being an infinitesimal of a lower order. We also have

$$\text{area } b c d e = \int dp \, dv = d\tau \int \frac{dp}{d\tau} dv = m_2 b c d m_5 - m_2 b e d m_4.$$

Substituting,

$$K_v \, d\tau + \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2 p}{d\tau^2} dv \, . \, d\tau + d\tau \int \frac{dp}{d\tau} dv - K_{v''}$$

$$- \tau \int \frac{dp}{d\tau} dv = d\tau \int \frac{dp}{d\tau} dv.$$

Cancelling and reducing,

$$K_v = K_{v''} - \tau \int_{v}^{v''} \frac{d^2 p}{d\tau^2} dv = K_{v''} + \tau \int_{v''}^{v} \frac{d^2 p}{d\tau^2} dv.$$

The difference between the specific heats at the volumes v and v'' is due to the internal work during the expansion along $c\,d$, exceeding that along $b\,e$.

If v'' be removed so far from v that the gas becomes perfect, then $K_{v''}$ will, according to Rankine's hypothesis, be constant, and we will represent it by C_v in place of his old English k. Further, the expansion necessary to give this result is assumed to be indefinite, so that v'' will be infinite, and also the relation between p and τ is assumed to be a continuous function, for otherwise the integration could not be performed, so that we finally have

$$d\,H = C_v\,d\,\tau + \left[\tau \int_{\infty}^{v} \frac{d^2\,p}{d\,\tau^2}\,d\,v\right] d\,\tau + \tau\,\frac{d\,p}{d\,\tau}\,d\,v \qquad (2)$$

which is Rankine's equation (2), page 312.

It is well to observe that $d\,v$ in the second term is involved in a different operation from that in the third term; the latter being a part of the actual operation in passing from a to c, *Fig. 3*, while the former is a purely ideal one for determining a value for the variable specific heat at v. In order to reduce the second term, the equation of the gas must be known. Thus, if it be

$$p = R\,\frac{\tau}{v} - \frac{a}{\tau\,v^2}$$

as it is for carbonic acid gas, then considering v as constant during the differentiation,

$$\frac{d^2\,p}{d\,\tau^2} = -\,\frac{2\,a}{\tau^3\,v^2},$$

then integrating, considering τ as constant, since the integration is along the isothermal $b\,e$,

$$\int \frac{d^2\,p}{d\,\tau^2}\,d\,v = -\,\frac{2\,a}{\tau^3} \int_{\infty}^{v} \frac{d\,v}{v^2} = \frac{2\,a}{\tau^3\,v},$$

and the second term of equation (2) becomes, for this particular gas,

$$\left(\frac{2\,a}{\tau^2\,v}\right) d\,\tau$$

The value of the expression $\frac{2\,a}{\tau^2\,v}$ is so small for known gases,

compared with C_v that it may generally be omitted. Thus, for carbonic acid gas

$$a = 3{\cdot}42 \times 17264 \times 8{\cdot}1572,$$

and if the temperature be that of melting ice, 493°·2 F., at the pressure of one atmosphere, then

$$\frac{2\,a}{\tau^2\,v} = \frac{2 \times 3{\cdot}42 \times 17264 \times 8{\cdot}1572}{(493{\cdot}2)^2 \times 8{\cdot}1572} = 0{\cdot}42 +,$$

while C_v is about 132. Since it is impossible to find the value of C_v with perfect accuracy, it is apparent that 0·42 may be omitted without sensible error, since it falls within the limits of the errors of observation.

The integral of equation (2) between the limits belonging to the conditions of the problem, would give the heat absorbed. But it is impossible to find the general integral; it may, however, be found in the following cases:

(1.) When the gas is perfect and the equation of the path described is known.

(2.) When the gas is imperfect, its equation being known, and the expansion isothermal.

(3.) When the pressure and temperature are constant during expansion.

CASE I.

For a perfect gas we have

$$p\,v = R\,\tau;$$

$$\therefore \left(\frac{d\,p}{d\,\tau}\right)_v = \frac{R}{v},$$

$$\left(\frac{d^2\,p}{d\,\tau^2}\right)_v = o,$$

which, substituted in equation (2), gives

$$d\,H = C_v\,d\,\tau + R\,\frac{\tau}{v}\,d\,v$$

$$= C_v\,d\,\tau + p\,d\,v$$

which, integrated, gives

$$H_{a,b} = C_v\,(\tau_2 - \tau_1) + \int_{v_1}^{v_2} p\,d\,v. \qquad (3)$$

The several terms of this equation may be illustrated by means

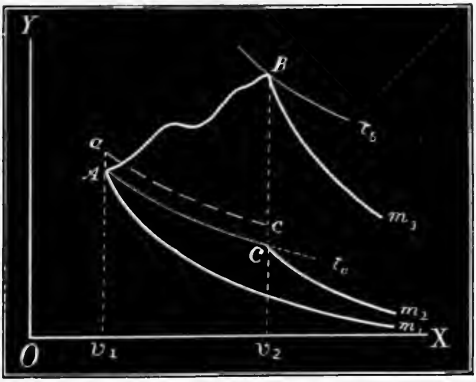

FIG. 5.

of *Fig. 5*. Let A and B be respectively the initial and terminal states of the gas, the line $A\ B$ being the path of the gas in expanding from v_1 to v_2. The last term, or

$$\int_{v_1}^{v_2} p\ d\ v$$

is the external work done, and equals $v_1\ A\ B\ v_2$, and since the gas is perfect, the heat absorbed will be represented by the same area. Through A draw the isothermal $A\ C$, and through A, C, B, respectively, the adiabatics; then, according to the second law, the heat absorbed, while generating the path $A\ C$, will be

$$\text{area } m_1\ A\ C\ m_2 = v_1\ A\ C\ v_2.$$

The area $A\ C\ B$ represents at the same time a portion of the external work and a corresponding equal quantity of heat; hence

$$m_1\ A\ B\ C\ m_2 = v_1\ A\ B\ v_2.$$

The term

$$C_v\ (\tau_2 - \tau_1)$$

will be represented by the area $m_2\ C\ B\ m_3$, τ_2 being the temperature of the substance at the state B, and τ_1 at the states A and C; hence the second member will be represented by the area $m_1\ A\ B\ m_3$, which represents the heat absorbed in passing from the state A to the state B, and indicated by $H_{a,b}$.

Let the equation of the path of $A\ B$ be known, or

$$p = \varphi\ (v),$$

in which case the area $v_1\ A\ B\ v_2$ may be found. To be more

specific, let the path be a straight line, whose equation is

$$p = a + b\,v,$$

then

$$\int p\,d\,v = \int_{v_1}^{v_2} (a + b\,v)\,d\,v,$$

which is easily reduced.

CASE II.

When the temperature is constant, we have $d\,\tau = o$, and equation (2) becomes

$$d\,H = \tau\,\frac{d\,p}{d\,\tau}\,d\,v.$$

Let the equation of the gas be

$$p\,v = R\,\tau - \frac{a}{\tau\,v}. \tag{4}$$

then

$$\tau\left(\frac{d\,p}{d\,\tau}\right)_v = R\,\frac{\tau}{v} + \frac{a}{\tau\,v^2} \tag{5}$$

$$= p + \frac{2\,a}{\tau\,v^2}; \tag{6}$$

$$\therefore d\,H = \left(p + \frac{2\,a}{\tau\,v^2}\right) d\,v;$$

hence for an isothermal expansion

$$H_{a,\,b} = \int_{v_1}^{v_2} p\,d\,v - \frac{2\,a}{\tau}\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$= \int_{v_1}^{v_2} p\,d\,v + \frac{2\,a}{\tau}\left(\frac{1}{v_1} - \frac{1}{v_2}\right), \tag{7}$$

the last term of which is the internal work done during the expansion, and may be represented by *area A a b B, Fig. 6.*

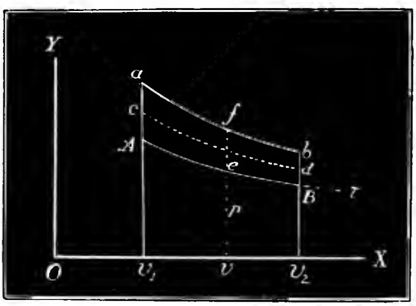

FIG. 6.

The external work will be

$$v_1 A B v_2 = \int p\, d\, v = \int_{v_1}^{v_2} \left(R \frac{\tau}{v} - \frac{a}{\tau\, v^2} \right) d\, v$$

$$= R\, \tau\, log\, \frac{v_2}{v_1} - \frac{a}{\tau} \left(\frac{1}{v_1} - \frac{1}{v_2} \right)$$

which, substituted in (7), gives

$$H_{a,\,b} = R\, \tau\, log\, \frac{v_2}{v_1} + \frac{a}{\tau} \left(\frac{1}{v_1} - \frac{1}{v_2} \right)$$

We note here an interesting fact in regard to the actual and the virtual pressures. Let $A\, B$ be the isothermal of the gas whose equation is (4) above. If now it were possible to remove the imperfection, all other qualities remaining the same, the ordinate p would gradually increase, and when a becomes zero, we would have the equation of a perfect gas, or,

$$p = R \frac{\tau}{v}.$$

Let $c\, d$ be the isothermal in this case. Or, to put it another way, assume $a = o$, and find the corresponding isothermal $c\, d$; then, from equation (4),

$$A\, c = \frac{a}{\tau\, v^2}.$$

But the virtual ordinate doing the internal work, is, from equation (6),

$$\frac{2\, a}{\tau\, v^2} = A\, a,$$

from which it appears that

$$a\, c = c\, A.$$

As a physical explanation of the manner of producing this result, conceive that the gas is perfect, then at the volume v_1 the pressure will be $c\, v_1$. Now conceive that the gas undergoes such a change, so as to become imperfect; not only would the pressure fall, as shown by equation (4), but because internal work is being done, the temperature would fall, and hence to maintain the initial temperature, the substance must absorb heat, to represent which the *virtual* pressure must be increased, so that while A falls below c, a will rise above. The distance $A\, c$ will equal $c\, a$ only when the equation of the gas is of the form of equation (4).

CASE III.

When p and τ are both constant, equation (2) becomes

$$H = \tau \frac{d p}{d \tau} \int_{v_1}^{v_2} d v$$

$$= \tau \frac{d p}{d \tau} (v_2 - v_1), \qquad (8)$$

which is applicable to cases of fusion and of evaporation.

Returning now to the general equation (2), we observe that in the third term, the factor $\tau \frac{d p}{d \tau}$ may, in all cases, be considered as a *virtual pressure*, such that being multiplied by $d v$, gives an element of the work, both external and internal, for the expansion $d v$. Subtracting the external work, $p\, d v$, gives the internal work due to expansion; hence adding and subtracting $p\, d v$, equation (2) becomes

$$d H = C_v d \tau + \tau \int_{\infty}^{v_2} \frac{d^2 p}{d \tau^2} d v \,.\, d \tau + \left(\tau \frac{d p}{d \tau} - p\right) d v + p\, d v$$

or, integrating,

$$H_{a,b} - \int_{v_1}^{v_2} p\, d v = C_v (\tau_b - \tau_a) + \int \left[\tau \int_{\infty}^{v} \frac{d^2 p}{d \tau^2} d v \,.\, d \tau \right.$$

$$\left. + \left(\tau \frac{d p}{d \tau} - p\right) d v \right], \qquad (9)$$

the last term of which represents the internal work done due to changes of temperature and volume. *The resultant internal work is dependent only upon the initial and final states of the gas and not upon the intermediate path.*

To illustrate this point, suppose that in passing from A to B, *Fig. 5*, the temperature at some part of the path were made to exceed that at B by 50°, more internal work would be done in raising the temperature this amount, than if it had not been made to exceed that of B; but in the remainder of the path, in bringing the temperature down from the 50° above B to that of B, the excess of internal work that had been performed will be undone, and the final result upon reaching B will be the same as if the temperature had in no part of the path exceeded that of B.

Similarly, the resultant internal work done by expansion will be the same, whether the expansion increases directly from v_1 to v_2, or whether there be expansions and compressions. Thus suppose that some part of the path in passing from A to B should be five feet to the right of the $v_2 B$, more internal work would be done in producing this five feet of expansion than if the expansion were limited to v_2, but in reaching the state B, there must be a compression of these five feet, so that the previous extra internal work will be undone, the final result being the same as if the path did not cross the ordinate $v_2 B$. The same reasoning would apply if the path passed to the left of $v_1 A$. The external work, $v_1 A B v_2$, is dependent upon the path $A B$. This being the case, we may choose the path along which we may conceive the substance to be worked in order to determine the internal work, which path may have no relation to the one actually described in doing external work; and such a path may be chosen as will favor the algebraic analysis. In *Fig. 5*, conceive that the fluid is expanded along the isothermal $A C$ from v_1 to v_2, thence at the constant volume v_2 the pressure is raised from C to B; then will the internal work be

$$\text{from } A \text{ to } C, \int_{v_1}^{v_2} \left(\tau \frac{d p}{d \tau} - p \right) d v, \tag{10}$$

in which τ is constant, and is represented by $A\, a\, c\, C$, *Fig. 5*, and

$$\text{from } C \text{ to } B, \int_{\tau_0}^{\tau_b} \int_{\infty}^{v_2} \tau \frac{d^2 p}{d \tau^2} d \tau\, d v, \tag{11}$$

in which v is constant in determining $\frac{d^2 p}{d \tau^2}$ from the equation of the gas, but variable in reference to the integral, and τ variable throughout the operation. The last expression is not written in the order given by the author, but is made to conform to modern forms involving successive integrations; according to which all the terms involving v are integrated between proper limits, after which the remaining integral is performed. Since v and τ are entirely independent of each other, the integrations in this case may be performed in reverse order, with the same final result. The fact that τ is treated as constant in the first integration, makes it proper to place it before the integral sign, as in equation (9), but

it is unnecessary to state that it is equally correct to place it after the integral sign as in (11), both forms producing the same final value. The conditions of the solution make $\tau_a = \tau_c$.

As a special example illustrating the use of equations (10) and (11), let the equation of the gas be as given in equation (4), then equation (6), substituted in (10), gives—

$$\int_{v_1}^{v_2} \frac{2\,a}{\tau_a v^2}\,d\,v = \frac{2\,a}{\tau_a}\left(\frac{1}{v_1} - \frac{1}{v_2}\right), \qquad (12)$$

and from (4) find

$$\tau \frac{d^2\,p}{d\,\tau^2} = \frac{2\,a}{\tau^2\,v^2},$$

which in (11) gives

$$\int_{\tau_c}^{\tau_b}\int_{\infty}^{v_2} \frac{2\,a}{\tau^2\,v^2}\,d\,\tau\,d\,v = -\frac{2\,a}{v_2}\int_{\tau_c}^{\tau_b}\frac{d\,\tau}{\tau^2} = \frac{2\,a}{v_2}\left(\frac{1}{\tau_c} - \frac{1}{\tau_b}\right) \qquad (13)$$

The entire internal work done in passing from state A to state B will be the sum of the values in equations (12) and (13), and is represented by ΔS, in the *Steam Engine*, page 304, and in some other places simply by S. Hence, in this case,

$$S = 2\,a\left[\frac{1}{\tau_a}\left(\frac{1}{v_1} - \frac{1}{v_2}\right) + \frac{1}{v_2}\left(\frac{1}{\tau_c} - \frac{1}{\tau_b}\right)\right] = 2\,a\left[\frac{1}{\tau_a\,v_1} - \frac{1}{\tau_b\,v_2}\right] \qquad (14)$$

which admits of a numerical value when a and the initial and final limits are known.

The author, in the article under consideration, uses S_a and S_b for the values of the potential energy necessary to overcome molecular forces in expanding unity of weight of a substance from the states A and B, respectively, to that of a perfect gas; the last clause of which simply means that the gas is expanded indefinitely.

We may conceive the fluid worked along other paths than those just indicated in *Fig. 5;* for instance, it may be worked along the adiabatic $A\,m_1$ indefinitely, becoming asymptotic with the adiabatic through B, and then compressed along $m_3\,B$ to B, in which case, we have

$$S_a = \int_{v_1}^{\infty}\left(\tau\,\frac{d\,p}{d\,\tau} - p\right)d\,v,$$

$$S_b = \int_{v_2}^{\infty} \left(\tau \frac{d\,p}{d\,\tau} - p\right) d\,v,$$

as shown in *Fig.* 7, in which τ, p and v are all variable, but the

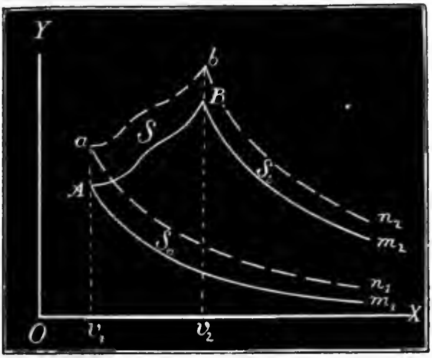

FIG. 7.

integration cannot be performed under these conditions, even if the equation of the adiabatic were known, for there would be two variables after elimination, one dependent upon the other.

Since all isothermals of the same gas are mutually asymptotic, one may pass from A outward on the isothermal τ_a, indefinitely, and back to B on the isothermal τ_b. In this case, we have

$$S_a = \int_{v_1}^{\infty} \left(\tau_a \frac{d\,p}{d\,\tau} - p\right) d\,v \tag{15}$$

$$S_b = \int_{v_2}^{\infty} \left(\tau_b \frac{d\,p}{d\,\tau} - p\right) d\,v \tag{16}$$

which may be integrated, since τ will be constant. In passing from A to B, thence, indefinitely, along the isothermal τ_b, and finally back to A along the isothermal τ_a, the sum of the internal works will be zero, or

$$S + S_b - S_a = 0;$$

$$\therefore S = S_a - S_b \tag{17}$$

In passing from state A to state B, the total heat absorbed will equal the total work done, internal and external, added to the increased energy of the substance; hence, or by equation (9),

$$H = \int p\,d\,v + S + C_v(\tau_b - \tau_a),$$

or, in the form given by the author, after substituting from (17),

$$H - \int p\, d\, v = (C_v\, \tau - S)_b - (C_v\, \tau - S)_a \qquad (18)$$

which is the author's equation (2), page 313

If A and B are in the same vertical through v_2, no external work will be done in passing from state A to state B, hence

$$\int p\, d\, v = 0,$$

and

$$H = (C_v\, \tau_b - S_b) - (C_v\, \tau_a - S_a).$$

If A be at the foot of the perpendicular $B\, v_2$, then

$$\tau_a = 0,$$

and

$$H = C_v\, \tau_b - S_b + S_a$$
$$= C_v\, \tau_b + S \qquad (19)$$

in which S is the internal work done in raising the temperature from zero to τ_b.

If the gas were perfect, the entire energy, $C_v\, \tau$, would be expended in doing external work by an indefinite adiabatic expansion, a fact easily verified by showing directly that the area $m_1\, A\, v_1\, X$, *Fig. 5*, indefinitely extended, equals $C_v\, \tau_a$; and the entire area under the adiabatic represents the *intrinsic* energy of a perfect gas. But if the gas be imperfect, a part of the energy possessed by the substance will be expended in overcoming its own molecular attractions during expansion, so that the external work which it can do is less by the amount of internal work so done; hence, in the state B, the *intrinsic* energy, or the external work which it can do by virtue of the energy it possesses, by an indefinite expansion, will be

$$C_v\, \tau_b - S_b,$$

and similarly for the state A. This is also the area under the adiabatic of the imperfect gas, but the area is less for the same temperature.

To ascertain if equations (15), (16), (17), will give the same result as (12) and (13) for the particular gas here considered, we find in the same manner as in equation (12), which is the same as (15) when $v_2 = \infty$,

$$S_a = \frac{2\, a}{\tau_a\, v_1};$$

similarly,

$$S_b = \frac{2\,a}{\tau_b\,v_2};$$

which, in (17), give

$$S = 2\,a\left(\frac{1}{\tau_a\,v_1} - \frac{1}{\tau_b\,v_2}\right)$$

which is the same as (14); hence, the two processes give the same results in this case.

In the same manner, the two processes may be verified for the more general equation of imperfect fluids, which, as given by Rankine, and verified to some extent by Regnault, is

$$\frac{p\,v}{p_0\,v_0} = \frac{\tau}{\tau_0} - a_0 - \frac{a_1}{\tau\,v} - \frac{a_2}{\tau^2\,v} - etc.,$$

in which a_0, a_1, a_2, are functions of the density, and assuming them to be inverse functions of the specific volume, and multiplying through by $p_0\,v_0$, it may be written,

$$p = R\,\frac{\tau}{v} - \frac{A_0}{v} - \frac{A_1}{\tau\,v^2} - \frac{A_2}{\tau^2\,v^2} - etc.$$

From this find

$$\int_{v_1}^{v_2}\left(\tau_a\frac{d\,p}{d\,\tau} - p\right)d\,v = \left(A_0 + \frac{2\,A_1}{\tau_a} + \frac{3\,A_2}{\tau_a^{\,2}} + etc.\right)\left(\frac{1}{v_1} - \frac{1}{v_2}\right),$$

$$\int_{\tau_a}^{\tau_b}\int_{\infty}^{v_2}\frac{d^2p}{d\,\tau^2}\,\tau\,d\,\tau\,d\,v = \frac{2\,A_1}{v_2}\left(\frac{1}{\tau_a} - \frac{1}{\tau_b}\right) + \frac{3\,A_2}{v_2}\left(\frac{1}{\tau_a^{\,2}} - \frac{1}{\tau_b^{\,2}}\right) + etc.,$$

the sum of which is

$$S = \left(A_0 + \frac{2\,A_1}{\tau_a} + \frac{3\,A_2}{\tau_a^{\,2}} + etc.\right)\frac{1}{v_1}$$
$$- \left(A_0 + \frac{2\,A_1}{\tau_b} + \frac{3\,A_2}{\tau_b^{\,2}} + etc.\right)\frac{1}{v_2}. \qquad (20)$$

Equations (15) and (16) give

$$S_a = \left(A_0 + \frac{2\,A_1}{\tau_a} + \frac{3\,A_2}{\tau_a^{\,2}} + etc.\right)\frac{1}{v_1}$$

$$S_b = \left(A_0 + \frac{2\,A_1}{\tau_b} + \frac{3\,A_2}{\tau_b^{\,2}} + etc.\right)\frac{1}{v_2},$$

which in (17) give precisely the same value for S as just found in equation (20). No further verification of the analysis is needed.

If, in (20),

$$A_0 = 0,\ A_1 = a,\ A_2 = 0,$$

it becomes

$$S = 2a\left(\frac{1}{\tau_a v_1} - \frac{1}{\tau_b v_2}\right)$$

which is the same as (14). In this, if

$$\tau_a v_1 = \tau_b v_2,$$

the internal work for this gas in working from state *A* to state *B* will be zero. If external work be done in this case, we have

$$v_2 > v_1;$$

$$\therefore \tau_b < \tau_a$$

and if the final temperature exceed the initial, work must have been done upon the gas since v_2 will be less than v_1; for

$$v_2 = v_1 \frac{\tau_a}{\tau_b},$$

the result being produced by compression during the absorption of heat.

Recognizing the fact that the matter treated in the pages of the *Steam Engine*, here considered, is so greatly condensed as to make it exceedingly difficult for the student to surmount the difficulties encountered, we have considered it better to err, if at all, on the side of unnecessarily minute explanations, rather than assume an amount of knowledge of the subject by the reader.

ALUMINIUM AND ITS ALLOYS; WITH EXPERIMENTAL INVESTIGATIONS.

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(*Continued from Vol. CXXIII, page 226.*)

ALUMINIUM ALLOYS.

The alloys of aluminium form a subject that will doubtless be of the greatest interest to the engineer of the future. They are exceedingly numerous, and the range of proportions of the ingredients to produce useful alloys is very wide. In a general way, aluminium may be said to improve the qualities of every metal to which it is added in small quantities. It increases the strength and lustre of the softer metals and renders others much less liable to corrosion. It alloys with nearly all the useful, as well as precious, metals. When alloyed with iron, it cannot be entirely separated in a metallic form. Iron containing over seven or eight per cent. of aluminium becomes brittle and crystallizes in long needles.

Alloyed with a small per cent. of silver, it loses much of its malleability; but with five per cent. of silver it can be worked well, and takes a more beautiful polish than the pure metal. With three per cent. of silver, it is very suitable for philosophical instruments, being harder and whiter than the pure metal, and is not tarnished even by sulphuretted hydrogen.

With small amounts of silver, it appears very suitable for scale-beams, and is now frequently used for this purpose. The alloy containing five per cent. of silver has often been suggested for coin of small denominations, as it is hard, bright and retains its lustre in handling.

With tin, several characteristic alloys of no importance are formed. They are, in general, hard, brittle and slightly malleable.

The most interesting alloy with zinc contains three per cent. of aluminium. It is harder than either metal, and the brightest of all the alloys we are considering.

* Graduation Thesis, 1886.

The presence of bismuth, as might be expected, produces brittleness.

Ninety-seven per cent. of gold and three per cent. of aluminium give a more beautiful color to the gold, and yet the latter metal does not lose in ductility or malleability.

It can be seen from even the brief sketch of alloys given, that the introduction of small quantities of foreign metals into aluminium improves its brilliancy and hardness without very greatly injuring its other properties; while the properties of other metals are almost invariably improved by the addition of small amounts of aluminium.

The most important alloys, and next to be considered, are the alloys with copper. These form a striking series, of which the alloy of ten per cent. of aluminium and ninety per cent. of copper is the most prominent.

This compound was discovered as early as 1856, by John Percy, and its wonderful properties were soon partly recognized, and it received the name of aluminium-bronze, which has subsequently been extended to other compositions containing different per cents. of copper.

Early mention is made of the excellent qualities of this bronze in the *Comptes Rendus*, where its application for rollers is stated to have given much better results than ordinary bronze.

It was never made in appreciable quantities until about 1867. In observing the different alloys with copper, we notice a gradual change in properties as the copper is increased in amount. Aluminium can contain ten per cent. copper, and still retain most of its malleability. Exceeding ten per cent., however, it becomes brittle, but retains its white color up to nearly eighty per cent. The eighty-five per cent. alloy is brittle, but has a yellow color, and it is probable that the change in tint occurs at or about eighty-two per cent.

The ten per cent. aluminium-bronze possesses a deep golden color and has a specific gravity of 7·7. It can be forged and shaped at a red heat, and hammered until cold without cracking.

When it is made by a simple mixing of ingredients, it is brittle and does not acquire its best qualities until after having been cast several times. After three or four meltings, it reaches a maximum; at which point it may be melted several times without sensible

change. As it cools rapidly, large castings require some care to prevent cracking, so numerous runners and a large feeding-head should be employed. The ten per cent. bronze fuses at about the temperature of brass containing thirty-three per cent. zinc; and the five per cent. melts at a somewhat higher temperature. The former should be poured as cool as possible to produce sharp castings, and should be kept covered with charcoal up to the moment of pouring. Considerable care must be taken in the preparation of "risers," so that the metal will free itself of impurities. The metal can conveniently be freed from slag, or other impurity, when pouring into the mould, by the following method: A supplementary pot, or crucible, with a hole in its bottom, is secured over the pouring-gate of the mould. This hole is first plugged up by a carbon or iron rod heated to redness, and the pot is filled with the melted metal before the plug is withdrawn. This allows the oxide and slag to rise to the surface, and admits only pure metal to the mould. It also prevents the oxidation that a stream of metal would suffer in pouring through the air to the "pouring-gate," as is often practised.

The shrinkage of ten per cent. bronze in casting is about fifty per cent. more than ordinary brass.

Aluminium-bronze forges similarly to the best Swedish iron, but at a much lower temperature. It works best at a cherry red; if this is much exceeded, the metal becomes "hot short," and is easily crushed. The temperature for rolling is a bright red heat, and it is a curious fact that if the metal were forged at the temperature it is rolled, it would be smashed to pieces. If the temperature in the ordinary muffle in which it is heated be allowed to rise too high, the bronze will frequently fall apart by its own weight. When in the rolls, it acts very much like yellow Muntz metal. As it loses its heat much more rapidly than copper or iron, it has to be annealed frequently between rollings.

The following examples of rolling were given the author by the Cowles Electric Smelting and Aluminium Company: A billet of ten per cent. bronze, about 18″ x 1¼″ x 1¼″, was rolled in a Belgian train to quarter-inch rod, at one annealing The five per cent. bronze is harder to roll hot than the ten per cent., but in cold-rolling just the reverse is true; a piece of five per cent. sheeting, eight inches wide, has been reduced eight gauge numbers

when rolled cold, at one annealing; while a ten per cent. sheet could not be reduced more than half that number. The billets for rolling can best be prepared by casting in iron moulds previously rubbed with a mixture of plumbago, pipe-clay and lard-oil. The metal chills very quickly, and very smooth castings can be produced, the smoothness depending considerably on the speed of pouring. With care, the five and ten per cent. bronzes can be easily drawn into wire. It is preferable, however, to first roll the five per cent. to quarter-inch rods and the ten per cent. to a less diameter, and anneal them. The metal thus prepared is much tougher and less liable to break in drawing. The dies must be very hard, or the ordinary wire, and especially the higher grades, is apt to cut them. The speed of the draw-blocks must be less than for iron, brass, copper, german-silver, or soft steel, and the reduction must be more gradually effected.

Numerous tests have been made of the tenacity of the aluminium-bronzes in general, and the following are some of the results given by different experimenters and writers:

Rankine (*Ship-building*), ...	73,000	lbs. per square inch.
Anderson, ...	75,600	" " "
Seaton (*Marine Engineering*),	64,000 to 80,000	" " "

The following results were obtained at the South Boston Iron Works, with pieces of the Cowles Company's alloys, February, 1886:

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation Per Cent.*
10 per cent. Al B.,	91,463 lbs. per square inch,	. . .	1½
10 " "	92,441 " "	59,815	2½
10 " "	96,434 " "	85,034	1
9 " "	77,062 " "	51,774	9
9 " "	71,698 " "	44,025	9
8½ " "	72,019 " "	. . .	28½
7½ " "	60,716 " "	45,537	6

The length of above pieces between shoulders was six inches; diameter not given.

The following tests were made at the Washington Navy Yard, of pieces very nearly half an inch in diameter, and two inches between shoulders.

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation.*
10 per cent. Al B.	114,514 lbs. per sq. in.	. . .	0·45
10 " "	95,366 " "	69,749	·05
10 " "	109,823 " "	79,894	·05

The following results were obtained with specimens ·564 inch diameter, and four inches between shoulders, tested at the Watertown Arsenal.

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation.*
9 per cent., Al B,	71,800	. . .	8·25
8 " "	57,920	. . .	12·25

A number of remarkable and useful alloys are made by mixing aluminium-bronzes with nickel in various proportions. These compositions are said to be very ductile, and to have a tenacity of from 75,000 to over 100,000 pounds per square inch, with about thirty per cent elongation. Tests made by Kirkaldy on alloys of a similar nature made by the Webster Crown Metal Company, England, give results ranging from 82,000 to a little over 100,000.

The addition of a few per cent. of aluminium to common brass, greatly increases its tenacity and resistance to corrosion. Alloys containing copper, zinc and Al between the following limits:

Cu, ...	67 to 71 per cent,
Zn, ...	27½ " 30 " "
Al, ...	1¼ " 3 " "

and combined in different proportions, give tenacities from a little above 30,000 to over 65,000 pounds per square inch. Alloys with much less copper and more zinc—55·8 to 57 per cent. copper, and 42 to 43 per cent. zinc—approach nearer 70,000 pounds, and a specimen composed of

67·4 per cent. Cu,
26·8 " " Zn,
5·8 " " Al

broke at over 95,000 pounds tenacity per square inch.

An incident that occurred in the Imperial postage stamp manufactory, Paris, may be here cited as illustrating some of the peculiar properties of aluminium-bronze. Great trouble was experienced to procure a suitable die plate to place beneath the needles of a machine used for perforating sheets of postage stamps. At every blow, the needles passed through the holes in the die-plate, and as there were 300 needles making rapid strokes, about 180,000,000 holes were made per day! With this usage, brass plates wore out in a day, and even steel plates were speediiy destroyed. A plate of bronze being substituted, lasted for months without renewal.

The experiments of Strange showed that Al bronze possessed forty times the stiffness of ordinary brass and eight times that of ordinary bronze.

A suggestive statement is made by Guettier, to the effect that the resistance to traction of this bronze is 5·328 kilograms per square centimetre, whereas that of common ordnance bronze (Woolwich) is but 2·555 kilograms per square centimetre.

It is evident from the striking properties of the bronzes and alloys just described, that their applications would be almost limitless, could they at present compete with brass in price. They can not only be used wherever brass is employed, but can very often be made to take the place of iron or steel. Passing over the multitude of applications to articles of every-day use, the bronze has a tenacity and elongation that would easily fill the required standards for the wrought steel used by the British and German governments for cannon—which are about 70,000 pounds tensile strength and fifteen per cent. elongation. The guns referred to could be made of equal strength, in much less time and with less cost if the ten per cent. bronze were employed.

An alloy, made by the Webster Company, has been tried for propeller-blades, on a vessel whose bottom was subjected to the destructive influences of the waters of tropical rivers and oceans; the blades were in use for some time, and no appreciable results from galvanic action or corrosion were apparent.

For anti-frictional purposes, the alloys of aluminium seem well suited, and a peculiar compound, made by the Webster Company, has been used for steamship eccentric-straps, and received many encomiums from practical men. The Cowles bronzes have also run successfully for high speed bearings on dynamos.

For various household uses, the different alloys seem to be unexcelled. The golden color of the five per cent. bronze makes it very suitable for plumbers' and similar fittings, and its resistance to corrosion is greater than that of the materials generally used. For cooking utensils and even table-ware, these alloys are unsurpassed in color and durability. The color of gold and silver can be perfectly imitated without the offensiveness resulting from plating brass. Samples of table-ware made of Webster "white metal" were shown the writer, and appeared equal to silver in color and lustre, even after several months of indifferent treatment and exposure to New York City air.

There is at present one great drawback to the use of these bronzes for small manufactured articles—the difficulty of soldering. There is now no cheap and simple method of brazing Al bronzes, and they cannot be welded.

Pieces, however, can be united by the following jewellers' solders:

Hard solder for ten per cent. bronze, . . .	Gold, 88·88	per cent.
	Silver, 4·68	"
	Copper, 6·44	"
	100·00	
Middling solder for ten per cent. bronze, . .	Gold, 54·40	per cent.
	Silver, 27·60	"
	Copper, 18·00	"
	100·c0	

Soft solder for Al bronzes in general is made by adding brass to the ingredients already given, thus:

Brass, ...	14·30	per cent.
Gold, ...	14·30	"
Silver, ...	57·10	"
Copper, ...	14·30	"
	100·00	

The brass is composed of copper, seventy per cent., and tin, thirty per cent.

MANUFACTURE OF ALUMINIUM-BRONZES.

These bronzes have frequently been made in amounts large enough for testing, by melting together the correct proportions of copper and aluminium, but such a method will never be a commercial success while the ingredients have their present prices. The most economical way seems to be to make the alloys themselves as a first product, and reduce the alumina in the presence of copper.

The process of H. Niewerth, of Hanover, is briefly this: Ferro-silicium and fluoride of aluminium are mixed together in suitable proportions, and submitted to a red heat, which decomposes the bodies into volatile silicon fluoride, iron and aluminium, the latter forming an alloy with the iron. This alloy is then melted with copper, which, having a greater affinity for aluminium than has the iron, unites with the former to produce the bronze. After the mass has cooled and been broken, the iron can be separated without much difficulty.

Cryolite, or Al chloride, can be used in place of the fluoride. With the chloride, silicon chloride is produced.

We will now consider a new method of producing Al bronze, already briefly mentioned, and observe it in all its details, through the courtesy of its present manufacturers, who have kindly given the writer many interesting and instructive data concerning their process.

The furnace used by the Cowles Electric Smelting and Aluminium Company consists of a fire-brick box, 1 foot wide, 5 feet long and 15 inches deep. From opposite ends, enter two immense electrodes, that are really electric-light carbons, 3 inches in diameter and 30 inches long. These are partly contained in pipes that, in turn, pass through stuffing-boxes in the ends, to exclude the air, and, at the same time, admit of adjusting the electrodes.

To protect the walls of the furnace from the intense heat, it is lined with finely-powdered charcoal, which, having been first washed in a solution of lime-water, retains its non-conductivity even after the particles have been partially converted into graphite by heat.

The bottom of the furnace is now lined to a depth of two or three inches with this fine, prepared charcoal, and, by means of a sheet-iron gauge, the walls of the furnace are covered with charcoal to the thickness of two inches.

The charge, consisting of about twenty-five pounds of corundum, twelve pounds charcoal and carbon, and fifty pounds of granulated copper, is placed about the electrodes to within a foot of each end of the furnace. A layer of coarsely-broken charcoal is now spread over the charge, and the sheet-iron gauge withdrawn. The coarse charcoal on top allows the escape of carbonic-oxide gas formed during the process. An iron cover, lined with fire-brick, is luted on to prevent the entrance of air.

The charge is now prepared, and the furnace ready to be connected with an immense Brush dynamo—capable of producing ninety horse-power of electrical energy. In the circuit between the dynamo and furnace, is an ammeter, designed to register from fifty to 20,000 ampères of current, which is controlled by a large resistance-box, as the ends of the electrodes may at first be too close together to make it safe to start the dynamo. By watching the ammeter and moving the electrodes, the resistance-box can be

taken gradually out of circuit, without producing a "short circuit" at the beginning of the operation. In about ten minutes, after the copper about the electrodes has become melted, the latter are slowly moved apart until the current becomes steady. It is now increased to about 1,300 ampères and fifty volts. Carbonic oxide begins to escape from the orifices made in the top, and burns in two white plumes of flame. By regulating the distance between the electrodes, the current is kept constant for about five hours, and all parts of the charge are brought into the reducing zone.

When the operation is completed, a resistance is placed in the box and the current is switched into another furnace charged in a similar manner. The product is an alloy of copper containing fifteen to thirty per cent. of aluminium, and having a beautiful silver color when broken. The copper performs no part in the reduction, but is employed to absorb the aluminium, which would otherwise be converted into a carbide.

This alloy is now melted in an ordinary crucible-furnace and run into ingots, which, after being analyzed, are re-melted and sufficient copper added to produce the standard bronzes.

Two runs from the furnace described will produce about 100 pounds containing about fifteen per cent. of aluminium. From this data, it is estimated that pure metal can be produced, in its alloys, at about forty cents per pound, with a large plant at present in construction.

It is evident that a large electrical smelting plant need not be restricted to the production of aluminium and its bronzes, but also boron, sodium potassium, calcium, magnesium, chromium and titanium can be reduced by varying the details of operation.

The production of pure metallic aluminium still lacks some features necessary for its economical manufacture; but a complete solution of the problems of electric smelting will doubtless enable the metal to be placed on the market at a price that will insure for it an almost universal application.

EXPERIMENTAL INVESTIGATIONS.

The following is a description of experiments made by the writer, with specimens of aluminium-bronzes kindly furnished by the Cowles Electric Smelting and Aluminium Company. As the time devoted to this part of the work was necessarily curtailed,

owing to time spent on previous chapters, the writer does not regard his work as conclusive as to details, but believes that enough is here shown to point out the directions in which experimental investigations can be carried in the future that may be of interest and value. Such experiments may show that in certain applications the bronzes excel to a degree little thought of.

The exterior of the ingot used by the writer was a frosted gold color—the interior was of a brighter color, similar to that of new gold coins. After fastening to a planer-bed, test pieces were cut out for tension and torsion. The surface was naturally found to be harder than the interior, but was covered by a very thin skin. The centre of the pig on the upper surface showed what appeared to be bad cracks due to cooling; but on moving this surface the flaws were found to be surprisingly superficial. The bronze cut with great ease on the planer, the chips separating easily and quickly In this respect it works better than brass of equal hardness, and the tool leaves a surface of remarkable polish and lustre.

An illustration of toughness was shown when, after the "parting tool" had run almost to its depth, it became necessary to break-off the test piece which was held to the main piece of metal by a web about $9'' \times \frac{1}{16}'' \times \frac{1}{8}''$. As the piece showed too much ductility to be conveniently removed by using a cold chisel, a wrench was applied, and it was only after repeated efforts in bending backwards and forwards that the piece was finally removed. This piece was then cut in two, and standard torsion pieces were turned with square shoulders and a cylindrical portion $\frac{5}{8}$ inch diameter and 1 inch long. In doing this, it was found the metal cut dry on the lathe with great ease and smoothness. The speed of running being equal or higher than usually employed in turning brass, the chips came off very rapidly and exhibited no tenacity, as the feed at the same time was large. With a drill in good condition, a three-fourths inch hole can easily be bored on a small power lathe, care being taken to keep the hole clean and avoid unnecessary heating. Under the file, the metal worked similarly to brass, but does not clog to any serious extent. It is, however, much harder to cut with a "hack saw" than common brass.

(*To be continued.*)

TURBINES.

By Irving P. Church, C. E.,
Assistant Professor Civil Engineering, Cornell University.

In his introduction to Mr. Woodbridge's thesis on "Turbines," in the recent November and December numbers of this journal, Prof. Wood seems to imply that the former's solution, as based "upon the resolution of the pressures of elementary volumes and their moments," is the first employment of such a method.

Without the slightest desire to detract from the credit due to Mr. Woodbridge's achievements, it is perhaps permissible, in justice to the present writer, to state that this method of solution was developed by him several years ago and has been used in his classes at this institution ever since; with such variations in the details from Mr. Woodbridge's, however, as to render its publication in this journal of some interest to students of applied mechanics. It would have been published as a whole long before, had not the writer supposed that most teachers of applied mechanics would probably be led to discover it for themselves, in the effort to smooth the pathway of their pupils. Some portions have already appeared in periodicals, as will be mentioned presently, and these will not be repeated here, except as it may be desirable to present clearer and more direct proofs than those previously given.

The theory of the friction-less turbine consists mainly in the establishing of the first six equations of the article by the writer in this journal for May, 1884, (pp. 333 and 334), with the proviso that at whatever *uniform* angular velocity, ω, the wheel be run, the vane-tangent at entrance of wheel-channel is to coincide in direction with the relative velocity of the water issuing from the guides, and also that all channels are filled.

The question of the proper speed for maximum efficiency will not be entered upon here; Weisbach's treatment of that point being simple and clear, and exact enough for practical purposes.

Of these six equations, (3), (4) and (5), are too simple to need explanation here; (2) is Bernoulli's theorem for steady flow in a *fixed* pipe or channel, proved in all text-books on hydraulics, and dealing with the absolute velocity at entrance; (6) may be called

Bernoulli's theorem for a *rotating* pipe (in horizontal plane) and deals with relative velocities (it is also equation (6) in Mr. Woodbridge's thesis); while (1), the equation for *power* (work per unit of time), is founded on the principle of work and energy, and is assumed, without special proof, by Weisbach and Bresse.

Now it is a simple matter, by algebraic combination of some of these six equations, including (1), to deduce Rankine's expression for the power, as being equal to the difference in the *moment of the momentum* (of the mass of water flowing per unit of time) at entrance and exit, multiplied by the angular velocity. Hence, the establishment of Rankine's equation (call it equation (R); it is equation (8) in Mr. Woodbridge's article) by special proof is equivalent to the establishing of equation (1), and in our list of equations to be established, we may discard (1) and replace it by (R), if a student objects to (1) as obscure in principle. In such a case, therefore, it is important to prove (R) by as direct and convincing a method as possible, and such a method (by elementary volumes) is the one used by Mr. Woodbridge and the writer, not only for equation (R), but for (6).

Rankine's proof of equation (R) is very obscure to the beginner, and Prof. Unwin's, in the *Encyclopædia Brittanica*, though attempting to be more specific, seems extremely vague.

In the March number, 1880, of Van Nostrand's *Eng. Magazine*, may be found an article by the writer, in which the action of jets on vanes, and also the theory of the "turbine of free deviation" are investigated by the method of elementary volumes and their pressures. In the treatment of the former, attention is called to Rankine's neglect of a portion of the stream, as Mr. Woodbridge does in his recent paper; in treating the latter, the pressure of each element of the stream against the vane, at a given instant, is found, its moment about the wheel-axis formed, these moments summed, and this sum multiplied by the angular velocity ω to obtain the power exerted; the result of which (in equation (10) of that article) $= \omega \times$ change of "moment of the momentum" of the flow per unit of time; *i. e.*, this equation shows the truth of equation (R) for that particular case.

The form of proof of equation (R), prepared for the writer's classes, for any kind of turbine, will now be presented, consisting, as it does, of a consideration of the individual actions of all the

elementary vertical prisms into which we may divide the volume of water, which, at a given instant, occupies the wheel-channels.

Though following the same method (of elementary volumes) as that of Mr. Woodbridge, the present solution is, perhaps, less complicated, in that it does not require us to obtain a detailed expression for the pressure between each prism and the vane, while sacrificing nothing in rigidity of proof, nor in satisfactory minuteness of detail. It is convenient to divide it into three propositions:

PROP. I.—In any (outward- or inward-flow) turbine, if the pressures of the water against the vanes (or partitions between the channels) have reached a state of permanency, the wheel having a uniform angular velocity $= \omega$; then the work done by the water on the wheel per unit of time (or power) is

$$L = \omega \, \Sigma (P a) \tag{a}$$

in which $\Sigma\ (P\ a)$ denotes the *sum of the moments, about the wheel axis, of all the elementary pressures of the water against the vanes at any definite instant.* (These pressures are, of course, normal to the surface of the vanes at their respective points of application. This proposition calls for no proof here, and we accordingly pass on to

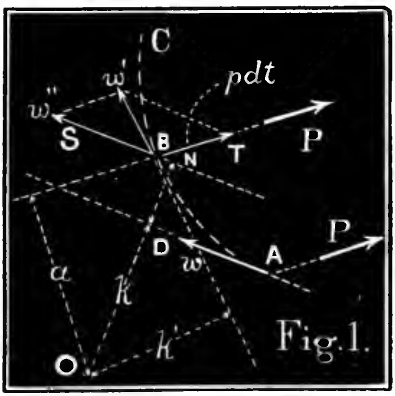

Fig. 1.

PROP. II.—Let M be the mass of a small particle or "material point," *Fig. 1*, which, in describing a plane curve, A, B, C, under the action of one or more forces. Let $A\ B$ be any element of the path, described in a time, $d\ t$, while P is the resultant of all the forces acting on the particle at this point of the path. Call the velocity at A, w; that at B, w'; the acceleration due to P, call p.

Of course, $p = P \div M$. By the principle of the composition of motions, w' is the diagonal formed on w'' at B, parallel and equal to the w at A, as one side, and $p\,d\,t$ the increment of velocity due to the action of P during $d\,t$, as the other side of a parallelogram.

From any point, O, in the plane drop perpendiculars upon w'', $p\,d\,t$, and w'; also, upon the w at A. Denote the lengths of these perpendiculars by the symbols shown in the figure. Then the same geometrical relation will hold between w'' ($= w$), w', and $p\,d\,t$, and their perpendiculars, as if $S\,T$ were a parallelogram of forces. That is,

$$w'\,k' = w''\,(k + \overline{DN}) - (p\,d\,t)\,a$$

(The negative sign is due to the circumstances of this particular figure).

But as the distance $A\ B$ is considered shorter and shorter, $\overline{D\,N}$, ultimately vanishes as compared with the finite k; hence we may write, since

$$w'' = w \text{ and } p = P \div M,$$

$$M\,(w\,k - w'\,k') = (P\,a)\,d\,t \tag{b}$$

or, more strictly, with full calculus notation,

$$M\,d\,(w\,k) = P\,a\,d\,t \tag{c}$$

That is, by multiplying the mass of the moving particles by the change which the product of its velocity by the perpendicular let fall upon the latter from any point, experiences in an element of time, $d\,t$, we obtain the product of $d\,t$ by the moment of the resultant force about the same point. (As is well known, this principle can be used to prove Kepler's law that the radius vector of a planet sweeps over equal areas in equal times.)

Prop. III.—*The sum of the moments about the wheel axis of the pressures exerted by the water in the wheel passages against the vanes at a definite instant, is equal to the loss (or gain) of "moment of momentum," between entrance and exit of the mass of water flowing per unit of time* ("moment of momentum" being a name given by Rankine to the product of the mass of a particle $\times$ its absolute velocity, $\times$ perpendicular distance of this absolute velocity from the arbitrary centre of moments).

Conceive the water which at any instant lies in the turbine passages to be subdivided into a great number of vertical rings,

concentric with the wheel, of *equal volume* and of such small thickness that at the end of the time $d\,t$, each ring fills the exact space occupied by its neighbor at the beginning of $d\,t$. (See *Fig. 2.*) The dotted line $M\,N$ shows the absolute path, and initial and final absolute velocities, w_1 and w_n, of a particle, as the ring to which it belongs passes completely through the wheel. In the small time

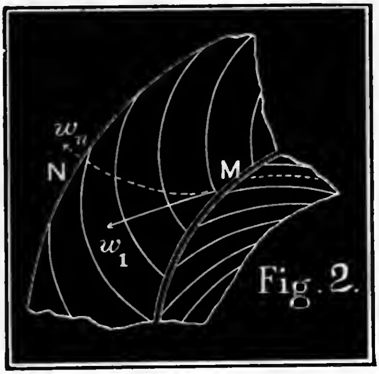

Fig. 2.

$d\,t$, in which any one ring passes into its consecutive position, the portion A (of the ring) included between any two neighboring partitions (see *Fig. 3,*) passes into a position A' in the next ring-space, and in this new position, on account of the "state of permanency" of the flow, has an absolute velocity, w', equal to that, w'', which the portion B had at the beginning of the $d\,t$, while the

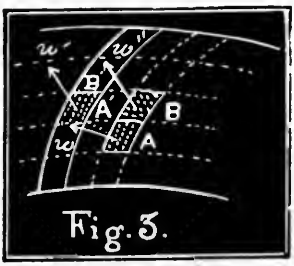

Fig. 3.

length of the perpendicular k', dropped on w' from the wheel axis, is the same in value as for B at the beginning of the $d\,t$, since the positions A' and B are in the same ring. In other words, the "moment" of the absolute velocity for A' (*i. e.*, the $w'\,k'$ of *Fig. 1*), about the wheel axis, at the end of $d\,t$, is the same in value as that for B, at the beginning of $d\,t$.

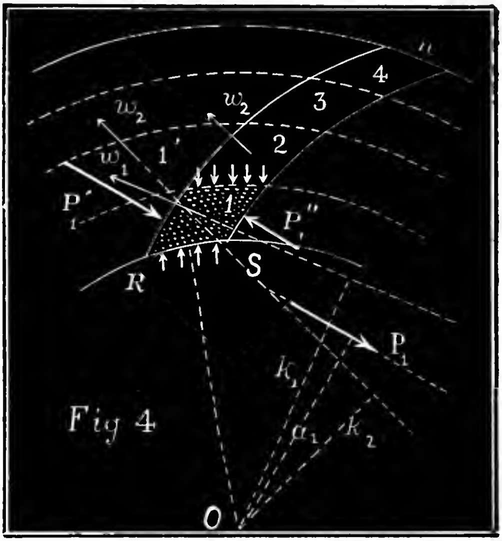

Fig 4

Now consider by itself (*i. e.*, as a "free body,") the prism 1, at the entrance of any one of the wheel channels, *Fig. 4*. P_1' and P_1'' are the pressures of the partitions against it; let P_1 represent their resultant; (it is, of course, the equal and opposite of the resultant pressure of this prism against the wheel at this instant). Since the pressures of the neighboring prisms against 1 have lines of action containing O the wheel axis, those pressures have no moments about O, and the moment $(P_1\, a_1)$ of P_1 about O is therefore equal to the moment about O of the resultant of P_1', P_1'', and the pressures on $L\,K$ and $R\,S$. During the time $d\,t$, prism 1 moves to position 1′ in the next ring-space, w_1 changes to w_2, k_1 to k_2. Hence, from Prop. II, equation (b) with $d\,M =$ mass of elementary prism, we have

$$d\,M\,(w_1\,k_1 - w_2\,k_2) = P_1\,a_1\,d\,t.$$

Similarly for the other prisms in this channel, between $R\,S$ and n, as they, simultaneously with 1, in time $d\,t$, move into their consecutive positions, we may write (remembering that all the $d\,M$'s are equal)

$$d\,M\,(w_2\,k_2 - w_3\,k_3) = P_2\,a_2\,d\,t$$

$$d\,M\,(w_3\,k_3 - w_4\,k_4) = P_3\,a_3\,d\,t$$

and so on, up to

$$d\,M\,(w_{n-1}\,k_{n-1} - w_n\,k_n) = P_n\,a_n\,d\,t.$$

Adding these equations, member to member, we obtain

$$\Sigma\,(P\,a) \text{ for one channel} = \frac{d\,M}{d\,t}\,(w_1\,k_1 - w_n\,k_n).$$

Hence, if the wheel has m channels

$$\Sigma\,(P\,a) \text{ for whole wheel} = \frac{m\,d\,M}{d\,t}\,(w_1\,k_1 - w_n\,k_n).$$

Now $m\,d\,M$ is the mass of water which leaves the wheel in time $d\,t$; hence, denoting by Q the volume of water passing per unit of time, and by γ the weight of a unit of volume, we have

$$m\,d\,M = \frac{Q\,\gamma}{g}\,d\,t$$

whence

$$\Sigma\,(P\,a) = \frac{Q\,\gamma}{g}\,[w_1\,k_1 - w_n\,k_n] \qquad \text{(d)}$$

$=$ the total moment with which the water acts on the wheel, as some would express it.

Finally, therefore, substituting from equation (a), we have the power of the wheel

$$L = \omega\,\Sigma\,(P\,a) = \omega\,\frac{Q\,\gamma}{g}\,[w_1\,k_1 - w_n\,k_n] \qquad \text{(e)}$$

which is equation (R), whose truth it was required to establish by a consideration of elementary volumes and pressures.

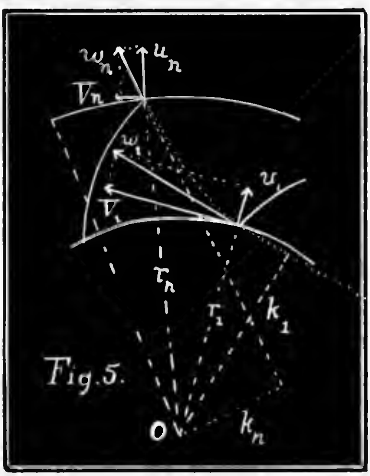

Fig. 5.

If, following Rankine's form of expression, we resolve the absolute velocities w_1 and w_n, of entrance and exit, of the water particles into components radial and tangential to the two circumferences of entrance, and exit, we may also write (from similar triangles)

$$L = \omega \frac{Q\gamma}{g}\left[V_1 r_1 - V_n r_n\right] \qquad \begin{matrix}(f)\\ \text{or } (R)\end{matrix}$$

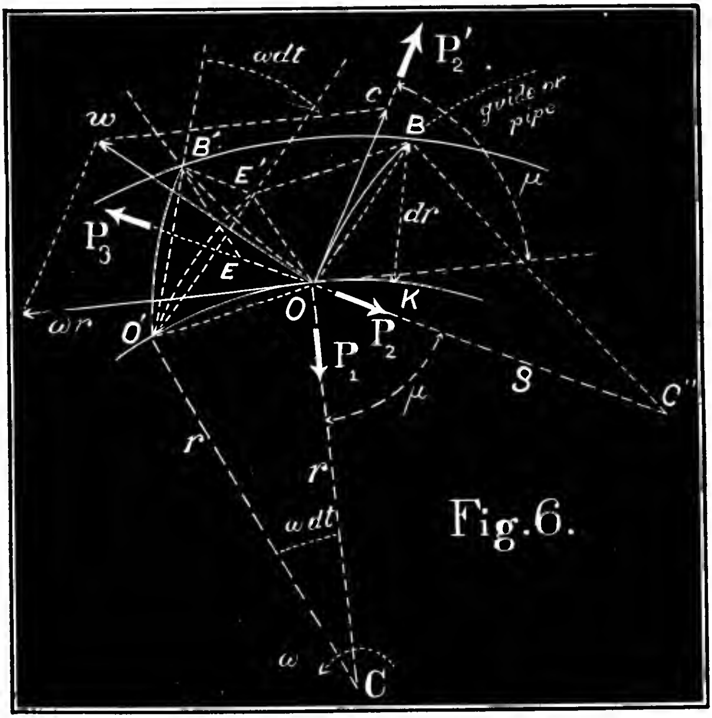

Fig. 6.

in which V_1 and V_n are the initial and final "velocities of whirl" as Rankine calls them, and r_1 and r_n the corresponding wheel radii. (This is Mr. Woodbridge's equation (8)).

We now pass to the proof of the equation referred to as (6) [both in Mr. Woodbridge's article and in that of the writer in Journal Franklin Institute, May, 1884,] showing the relation between the relative velocities and the pressures at entrance and at exit (Bernoulli's theorem for a uniformly rotating horizontal pipe or channel, as the equation might be called). The closely related

problem of the frictionless motion of a small solid or particle in a pipe of any form (of single curvature) rotating with a uniform angular velocity in a horizontal plane about a fixed axis (vertical, of course,) may be treated at the same time with but little extra detail, and is accordingly presented, being solved by a method of the writer's, not heretofore published in any periodical, but according to his experience, of a very direct nature in satisfying the student mind. In *Fig. 6*, $O\,B'$ is the absolute path described by the particle in a time $d\,t$; *i. e.*, in time $d\,t$ the pipe has rotated through an angle $\omega\,d\,t$, carrying O to O', and the particle itself, having at this instant a relative velocity $= c$ along the pipe, has described a distance $= c\,d\,t, = \overline{O\,B}, = \overline{O'\,B'}$, along the pipe. Let $\rho =$ the radius of curvature of the guide at this point, while r the radial distance of O and O' from the axis C is the radius of the circular arc $O\,O'$. The absolute velocity w, of the particle, is the diagonal formed on $\omega\,r$ and c, and by the principle of the composition of motions the absolute motion $O\,B'$ may be considered to result from the simultaneous compounding (by parallelograms) of the following component motions, viz.:

(*To be continued.*)

A NEW METHOD TO DETERMINE THE MOON'S MASS CORRECTLY, FOLLOWED BY A DISCUSSION UPON THE THEORY OF TIDES FULLY IDENTIFYING THE PHENOMENON UPON DYNAMICAL PRINCIPLES.

BY L. D'AURIA.

[*Presented in a Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, February 25, 1887.*]

Let $M =$ mass of the earth;

$\mu =$ mass of the moon;

$D =$ distance between their respective centres;

$\omega =$ angular velocity around their common centre of gravity;

$x =$ distance between this centre of gravity and that of the earth;

$\rho =$ radius of the earth at a latitude whose $sine = \dfrac{1}{\sqrt{3}}$;

$g =$ acceleration of gravity at such latitude;

$m = \frac{1}{g} =$ unit of mass;

$c =$ constant of attraction.

Then we have

$$\frac{c\ M\ \mu}{D^2} = M\ \omega^2\ x;\ M x = \mu (D - x).$$

Eliminating x, and solving for c, we find

$$c = \frac{D^3\ \omega^2}{M + \mu}$$

At a latitude whose *sine* $= \frac{1}{\sqrt{3}}$ the centre of attraction is found to coincide with the centre of figure of the earth (Laplace, *Mécanique Céleste*); therefore we can write

$$\frac{c\ M\ m}{\rho^2} = \frac{c\ \ M}{g\ \rho^2} = 1$$

from which

$$c = \frac{\rho^2 g}{M}$$

Comparing the above two expressions of c, we obtain the equation

$$\frac{\rho^2 g}{M} = \frac{D^3\ \omega^2}{M + \mu}$$

which gives

$$\frac{M}{\mu} = \frac{\rho^2\ g}{D^3 \omega^2 - \rho^2 g} \tag{1}$$

In this expression, ρ and g are constant, and their values are determined with all desirable accuracy. The term $D^3\ \omega^2$ should also be constant, since the ratio $\frac{M}{\mu}$ is a constant number under all circumstances. But taking into account the sun's disturbing force, we find that our fundamental equations can only be verified simultaneously when the earth and moon are in quadrature; for only then the common centre of gravity of the earth and moon coincides with the centre of gravity of such system with reference to the sun's attraction. Hence, in equation (1), we shall always mean for D and ω the values which correspond to the quadratures, and

which should be ascertained by a series of observations directed for such purpose.

However, if we take the mean values of D and ω and form the product $D^3\,\omega^2$, this cannot differ but little from the proper one, and in all probabilities the difference will not affect significantly the value of μ. In such case, if we put $D = n\,a$, in which a is the equatorial semi-diameter of the earth, we have

$$\frac{M}{\mu} = \frac{\rho^2 g}{n^3 a^3 \omega^2 - \rho^2 g} \qquad (2)$$

This expression can be very much simplified by finding the value of ρ in function of a. To this effect, if we denote by θ the latitude whose *sine* $= \frac{1}{\sqrt{3}}$, we have

$$a^2\,y^2 + b^2\,x^2 = a^2\,b^2;$$

$$y^2 = \rho^2\,sin^2\,\theta\,;\; x^2 = \rho^2\,(1 - sin^2\,\theta).$$

Hence

$$(a^2\,\rho^2 - b^2\,\rho^2)\,sin^2\,\theta + b^2\,\rho^2 = a^2\,b^2.$$

Substituting $sin\;\theta = \frac{1}{\sqrt{3}}$, we find

$$\rho^2 = \frac{3\,a^2\,b^2}{2\,b^2 + a^2}$$

Putting $\frac{a - b}{a} = \varepsilon = \frac{1}{298}$, and eliminating b, will be found after reductions

$$\rho^2 = \frac{a^2}{1{\cdot}00225}$$

Substituting in equation (2), we get

$$\frac{M}{\mu} = \frac{g}{1{\cdot}00225\,\omega^2\,n^3\,a - g}$$

Using the following data:

$a = 20{,}923{,}990$ feet (Clarke's mean value);
$g = 32{\cdot}18169$ "
$n = 60{\cdot}273433$ " (Herschel's tables);
$\omega = \frac{2\,\pi}{60 \times 39343{\cdot}183}$;

and assuming $M = 1$, will be found

$$\mu = \frac{1}{91{\cdot}75}$$

The value of μ adopted in Herschel's tables of lunar elements is $\frac{1}{88}$, which differs about three per cent. from our value. But it must be remembered that, since Laplace's first determination of the moon's mass, μ has been through the following series of values

$$\frac{1}{75}, \frac{1}{80}, \frac{1}{83}, \frac{1}{88},$$

showing how uncertain the methods hitherto employed are. In fact, with these methods, the mass of the moon is deduced from the effect its attraction produces upon the equatorial protuberance of the earth, which causes the nutation of the earth's axis; and also from the effect such attraction causes upon the waters of the oceans in proportion to that occasioned by the sun's attraction. Both these methods imply uncertain data, and involve the most abstruse resources known to astronomical science.

It may be that using the proper value for $D^3\,\omega^2$ in our equation (1), μ will be somewhat modified; but, unless the value of n given in Herschel's tables is not very accurate, we are inclined to think that the correction of μ would be very slight.

[In a letter elicited from Prof. Newcomb, of the Washington *Nautical Almanac*, we are informed, that, using the latest value of the moon's parallax, as determined by observation; that is, correcting n according to such value, our equation (1) would offer

$$\mu = \frac{1}{83{\cdot}4}.$$

By the observed constant of nutation and the observed value of the lunar equation in the motion of the earth around the sun, the same authority informs us that it has been found approximately

$$\mu = \frac{1}{81}.$$

It would seem that the value of n, given in Herschel's tables, is not sufficiently exact.]

(*To be continued.*)

BOOK NOTICES.

ELEMENTS OF GEODESY, for the use of students. By Prof. J. Howard Gore; Columbian University. New York: John Wiley & Sons. 1886.

We have just finished reading this interesting octavo volume of some 250 pages, well written and excellently printed. All who have given attention to the subject treated, will certainly feel gratified that a work of this description, so clear and concise, has issued from the American press. We may divide the treatise into two distinct parts. The first 100 pages may be said to be descriptive of the apparatus and processes relating to the art; and the remainder of the work treats of the methods of calculation, or of the mathematics involved. The latter has received the attention of many eminent mathematicians, but the student will find here their labors arranged for practice, with thorough knowledge of the subject. We can hardly praise this portion of the author's volume too much, nor commend too highly the typography; everything is as it should be. With regard to the descriptive portion, however, we have some criticisms to offer. Valuable information is certainly contained in it, yet more might have been added. The main apparatus of geodesy; that is, the measuring rods for bases and the transit for determining angles, are not explained and illustrated with the completeness necessary to initiate a student into the art. Although the work is professedly written for beginners, yet it is better adapted to practitioners as a hand-book, from lack of such full descriptions. In all good technical schools, the mathematics of geodesy may be taught by any professor of this branch of learning, but few such schools are provided with base rods and large transits to exhibit to students. Hence the need of full descriptions of them. Again, the self-taught student, who is often distant from the libraries of large centres of population, where alone additional works on geodesy are procurable, will not rest satisfied with the meagre remarks given in this treatise.

The author mentions merely the various kinds of base rods that have been used in different countries, and seems to consider, (contrary to our opinion,) the coast survey arrangement as the best one, which he explains more in detail than any other. We object to every measuring apparatus, whether for lines or angles, that consists of many parts, that is burdened with levers, screws, verniers, micrometers and microscopes. We object, especially, to movable parts. To resume, the author, in our opinion, should have added plates to his work, where every base apparatus mentioned by him should have been drawn to scale in a complete manner, so that they might have been reproduced, if necessary, in a workshop.

Opposite p. 35, is given a fine illustration of what seems to be the latest form of coast-survey transit. Now, we maintain that cross-sections also of the instrument should have appeared on additional plates, in order that its mechanism might become evident to a student. Critical remarks in regard to it might also have been added; for instance, the reasons given for the

introduction of the **U**-support to the telescope; for the use of three levelling-screws in place of four; for the conical shape of the limb, or graduated circle; for the use of a level on the latter; for the vertical clamp of the telescope; for the position of the horizontal clamp half-way between the microscopes; for the micrometer in the focus of the telescope, etc. Prof. Gore is apparently an advocate of the micrometer screw in opposition to the vernier, like most American and English geodesists. But we incline, with Continental practitioners in Europe, to the vernier, which we believe is virtually a superior arrangement for *field* instruments. The question is, really, not one between verniers and micrometer screws, but of accurate work in the *mechanism* and graduation of the instrument. What avails a fine reading of an angle when the metal of the instrument is not uniform in density and quality; when the graduation is too imperfect, the eccentricity too variable, the spindles and axes incorrectly made, and when the clamping screws press directly, with a rotary motion, on the axes and graduated plate? Lost or irregular motion in the spindles and telescope axes is the capital point; and to secure good work, we advocate that the construction of these portions of an instrument should be made a specialty by some manufacturer, provided with elaborate machinery for the purpose. The genius of our people for mechanism should overcome this difficulty.

In conclusion, we would respectfully suggest to the author that, in a second edition of his work, he will treat, with the completeness which the subject demands, the descriptive portion relating to field apparatus, and then we shall assuredly have a model work on geodesy. E.

OBLIQUE ARCHES. By John L. Culley. BEAMS AND GIRDERS. By P. H. Philbrick. New York: D. Van Nostrand. 1886.

We have received Nos. 87 and 88 of Van Nostrand's Science Series, on "Oblique Arches," by John L. Culley, and on "Beams and Girders," by P. H. Philbrick. Both of these small works are elementary in character, and well suited to introduce their respective subjects to beginners. Their small, compact form render them very portable, and their low price, accessible to all. Much, indeed, may be learned from them. E.

SCIENTIFIC NOTES AND COMMENTS.

ASTRONOMY AND PHYSICS.

RELATION BETWEEN CERTAIN SOLAR PHENOMENA AND VARIATIONS IN TERRESTRIAL MAGNETISM.—M. E. Marchand (*Comptes Rendus*, **104,** 133) details results of comparisons of variations of the magnetic elements (as observed at Lyon) with the position of spots and faculæ on the solar disc. Regarding the sum of the variations of the three magnetic elements reduced to the same unit, as the measure of the intensity of the disturbance, a suitable curve represents the changes of intensity of disturbance. Comparing this with the passage of spots and faculæ over the solar disc, he concludes that each maximum intensity of disturbance sensibly coincides with the passage of a group of spots or of a group of faculæ, by the point of its shortest distance from the centre of the solar disc. There seems to be no relation of amount of disturbance with diameter of the spots. There are, however, at times on the solar surface well marked regions of activity, whose passage over the central solar meridian, at successive rotations, is accompanied by magnetic disturbances quite as marked. Simple inspection of the curves of the recording instruments reveals the fact that great disturbances are separated by an interval sensibly equal to, or a multiple of, the apparent rotation of the sun.

M. B. S.

HARVARD COLLEGE OBSERVATORY.—(*Boyden Fund*).—By the will of the late Uriah A. Boyden, property, the present value of which exceeds $230,000, was left in trust for the purpose of astronomical research "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences."

The Trustees of this Fund have transferred the property to the President and Fellows of Harvard College, in order that the researches proposed by Mr. Boyden may be directed at the Harvard College Observatory. These researches will be supported by a portion of the means of the Observatory, in addition to the trust fund itself.

In order that the intentions of the donor may be successfully executed, it will first be necessary to obtain all practicable information with regard to the altitude, accessibility and climate of various mountainous regions which might naturally be selected as suitable places for the proposed observations. It will apparently be desirable that the work done at any selected station should be almost exclusively confined to that of observation, the records of which can be reduced and discussed to better advantage at the Observatory of Harvard College. For preliminary experiments one or more stations are required, at such altitudes that they will show what advantages are to be expected when the effect of the air is diminished. For the permanent station to be eventually occupied, it is probable that a very great altitude will be advisable. Ease of access is important, to permit the necessary instruments

and supplies to be transported. The climate must be such that the station can be occupied at all seasons of the year. A location in the southern hemisphere will be preferable for various reasons. The southern stars invisible in Europe and the United States have been less observed than the northern stars, and by the aid of a southern station the investigations undertaken at Cambridge can be extended upon a uniform system to all parts of the sky.

The Observatory of Harvard College accordingly desires to obtain all the information which can be of value, in view of the foregoing requirements, to enable a suitable station to be selected. It is hoped that some of the published and unpublished sources of such information may be sent as gifts to the Observatory. When this is not practicable, any information will be welcome which may lead to the purchase of such material. Records of meteorological observations made at considerable altitudes, books of travel giving full descriptions of mountainous regions, guide books and photographs of such places, will all be of much value for the purposes above mentioned.

Detailed information is also desired on the following subjects relating to any places which appear to fulfil the conditions of the trust.

(1.) Latitude and longitude. Distance and direction from some town, or other well known point. Height, and how determined.

(2.) Peak, pass, or table-land. Character of surface, ledge, broken rock, gravel, or covered with trees, shrubs, or grass. Prevalence of snow in summer, and period during which the depth of snow in winter might obstruct the paths of access, or occasion other inconvenience or damage. Proximity of wood for fuel, and of water.

(3.) Means of access, distance from and height above the nearest railroad station, wagon road, bridle path, or foot path. Time of ascent and descent. Nearest post-office and telegraph station, and their distances from the proposed station. Nearest point of road kept open in winter.

(4.) Observation of the rainfall at different seasons of the year. Proportion of the sky covered with clouds at different hours and seasons. These observations are desired at sunset, sunrise, and late in the evening. Such observations may also be made of a distant mountain peak, confining the evening observations to moonlight nights. Observations of the barometer and thermometer are also desired. Information is wanted regarding the prevalence of very high winds; the presence of dust, haze, or the smoke from forest fires, rendering distant points invisible; and all other meteorological phenomena affecting the value of the station for astronomical purposes. If there is a rainy or cloudy season, its duration; also the regular recurrence of clouds, thunder storms, or wind, at any given hour of the day.

(5.) Sketches or photographs of the proposed location, and of points on the road; also of the view.

Correspondence is invited with those residing near or in sight of suitable locations who are willing to undertake any of the observations described above, and also with any persons who have information of any kind likely to be useful in accomplishing the purposes of the trust established by Mr. Boyden.

EDWARD C. PICKERING,
Director of Harvard College Observatory.

Cambridge, Mass., U. S. A., March 1, 1887.

Disturbance of Astronomical Levels by an Earthquake.—Th. Albrecht (*Astron. Nachr.*, **116**, 130,) details the observation of remarkable disturbances in the levels during the Berlin-Breslau-Königsberg longitude determination, and as doubtless due to an earthquake wave. Individual observations of this character had been frequently made, but it had not hitherto happened that at three stations simultaneous observations should be made, which allowed *inter se* quantitative comparison.

On the morning of September 20, 1867, Wagner, of the Pulkova Observatory, had found the level of the transit instrument in such violent oscillation that no reading could be made; the greatest amplitude being 3″. An earthquake had taken place in Malta less than thirteen minutes previous, and the wave had consequently required that time to pass over an arc of 26° on a great circle. Among a number of other cases cited an observation made by Nyrén, at the Pulkova Observatory, May 10, 1877, is noteworthy; the disturbance having been traced to an earthquake at a point on the west coast of South America, Iquique, distant 112°·6 on a great circle from Pulkova, where the wave arrived one hour, fourteen minutes after the main shock had occurred.

The level disturbances here referred to occurred on the evening of August 2, 1885, and were simultaneously observed by Albrecht in Berlin, Richter in Breslau, and Borrass in Königsberg, and were, respectively, 2″, 4″ and 7″ in amplitude, and lasted about fifteen minutes at each station. The beginning of the disturbance could more accurately be got from the Berlin observations, and was set down as ten hours thirty-nine minutes Berlin M. T. A few days later, it was learned that a severe earthquake had occurred in Turkestan during the night of the 2d to 3d of August, the centre of disturbance being in North Latitude 42° 40′, East Longitude 74° 45′. In the city of Pischpek (Latitude 42° 50′, Longitude 74° 39′ East), the first and most severe shock occurred at ten hours, fifteen minutes Berlin M. T. The disturbance of the level at Berlin consequently began about twenty-four minutes later. Berlin being distant on a great circle from the earthquake centre 41°·1, the velocity of the wave is consequently 3·2 kilometres per second. As this value and that derived from the other cases here mentioned, is greater than that derived from ordinary seismological observations, these disturbances may have been due to the great depth of the centre of action. Particularly do these observations point to the desirability of constructing appliances for registering the condition of sensitive levels, as important means of furthering knowledge of the internal structure of the earth. M. B. S.

Periodic Variations of the Spots of Jupiter.—M. Lamey (*Comptes Rendus*, **104**, 5,) contributes some interesting results concerning the periodicity of the markings of Jupiter. M. Niesten, of the Brussels Observatory, had, from the great red spot of recent years, derived a period of variation of about six or seven years. M. Lamey, however, from a series of 583 drawings of this planet, covering a space of six years, concludes a periodic variation of about five and one-half years. As in the case of sun spots, the bands of Jupiter are subject to the same law of distribution in latitude.

These bands—ordinarily two in number—are to be found near the equator and near each other at an epoch which seems to precede the maximum of activity. Then follows a separation, and the formation of numerous secondary bands, until the motion of the bands in latitude leads to their disintegration, and, particularly in the northern hemisphere, to an absence at times of almost all markings. The period in its oscillation about a mean, is expressed in years as $5 \cdot 43 \pm 0 \cdot 07$, just as in the case of the sun we have $11 \cdot 11 \pm 0 \cdot 287$. The last equatorial concentration appears to have attained its maximum the twenty-third of March, 1885. M. B. S.

STELLAR PARALLAX DETERMINED BY PHOTOGRAPHY.—Rev. Prof. Pritchard (*M. N. Royal Astron. Soc.*, **47**, 87,) presents the results of some photographic experiments made at the University Observatory, Oxford, with the view of determining the parallax of 61^1 *Cygni* and 61^2 *Cygni*. This star was, of course, selected on account of the numerous determinations of its parallax since the noted measurements of Bessel; thus affording an excellent test of the new method. Four faint neighboring stars were selected for comparison, and the distances of these measured from each of the components of 61 *Cygni*, on some 200 plates, taken on fifty nights. The mean results, which, as yet, must be regarded as provisional only, are for 61^1 *Cygni*, parallax $0''\cdot 438$; for 61^2, parallax $0''\cdot 441$. The value of the parallax of 61 *Cygni* is, as determined by Bessel, $0''\cdot 348$; Auwers, $0''\cdot 564$; Ball, $0''\cdot 468$; Asaph Hall, $0''\cdot 478$. M. B. S.

Franklin Institute.

[Proceedings of the Stated Meeting, held Wednesday, March 16, 1887.]

HALL OF THE INSTITUTE, March 16, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, 194 members and 41 visitors.

Additions to membership since last meeting, eleven.

On behalf of the Special Committee on "State Weather Service," the Chairman, MR. W. P. TATHAM, made an oral report of progress.

The Secretary made a similar report on behalf of the La Cour-Delany Committee.

MR. GEORGE S. STRONG, of New York, read a paper on the "Strong Locomotive." The paper, with discussion thereon, has been referred for publication.

PROF. ELIHU THOMSON, of Lynn, Mass., read a paper on "Electric Welding," illustrating the same by the exhibition of a large collection of specimens, demonstrating the wide range of application of the new art. The paper, with discussion thereon, has been referred for publication.

The meeting thereupon proceeded to the consideration of certain propositions of the Committee on Reorganization for the Amendment of the By-Laws. Adjourned. WM. H. WAHL, *Secretary*.

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OF THE STATE OF PENNSYLVANIA,

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THE DAWN OF EGYPTIAN CIVILIZATION: A GLANCE AT THE FIRST DYNASTIES OF THE OLD EMPIRE.

BY GEORGE SÉLIKOVITSCH, PH. D.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *March 3, 1887.*]

DR. PERSIFOR FRAZER, in presenting the LECTURER, said that it was necessary, perhaps, to offer some explanation for the presentation of a subject of philological research in an Institution dedicated to the Mechanic Arts. But, firstly, the sisterhood of all methods of using the intellect has been established to such a degree, that the student of one domain is sure to be assisted by the victories in every other. Secondly, Egypt was more distinguished for originality, ingenuity, progress in commerce, manufactures, art, invention, literature, and profundity of thought in philosophy and religion, than any country which ever existed. The FRANKLIN INSTITUTE fosters those subjects of the above list in which the United States is in the van at the present date. There was, therefore, no lack of appropriateness in the inscription which Egypt placed over the department which was consecrated to her use, in the great universal exposition marking the first Centennial anniversary of our country: "From the oldest to the youngest nation."

But there is another and a utilitarian reason for the interest in Egypt on the part of those who maintain the standard of the FRANKLIN INSTITUTE; and that is, that our institution is the great depôt of patents in this city; and from recent developments in the establishment of priority in valuable inventions, by the courts, it would seem that we never could be assured of such priority until the last Egyptian inscription and papyrus had been deciphered. On behalf of the Committee on Instruction, and in the name of the President and Board of Managers of the FRANKLIN INSTITUTE, I have the honor of presenting Dr. George Sélikovitsch.

Dr. Sélikovitsch said:

LADIES AND GENTLEMEN:—Since Champollion, the great French archæologist, succeeded in deciphering the old writing of Egyptian hieroglyphics, at the beginning of the present century, the world has fixed its eyes on the ancient soil of the Pharaohs, rightly called, "the cradle of civilization."

With anxious curiosity, the learned archæologists of this day commenced to investigate the glorious remains, the dumb Sphinxes and the solitary Mummies of Memphis and Thebes. All these venerable ruins, which have escaped time's dilapidation, began to reveal to us the most extraordinary mysteries of ancient Egypt: her past; her religion; her philosophy; her poetry; her monarchs; her priests; her manners; her grandeur; and her decline.

We have all heard of Napoleon's famous sentence, "Soldiers! forty centuries look down on you from the pyramids." If the French monarch had known Egyptian history, he would have said: "Seventy centuries." Seven thousand years have, indeed, passed since the fourth King of the first Dynasty, Ouanephs, erected the pyramid at the town of Ka-Xemı, or "Black Bull." Six thousand years ago, Egypt was already an ancient country, with perfected language, laws and architecture:[1] I do not say, with a religion, because the deity had not yet a distinct designation.

Let us pass by the first three dynasties, which are still some-

[1] Various opinions have been expressed about the Egyptian chronology. Many savants have vainly tried to reconcile Egyptian chronology with the Biblical account of creation. Prof. Lesley, in his remarkable book, *Man's Origin and Destiny*, is of the number of Egyptologists who are rightly against this arbitrary reconciliation.

what wrapped in darkness, and begin at the fourth Memphite Dynasty.[1] Here, Egyptian history on the various monuments really begins. And what monuments! The great pyramid of Gizeh, the "splendor of pyramids," as it was called, was built by King Xufu (Cheops), successor of Snefru.[2] Yet, under this monarch, the æsthetic feeling is still obscure: "large" and "big" are synonymous with "beautiful" and "fine." The pious King Menkaura, Xufu's successor, seems to have given an important impulse to belles-lettres and fine arts, because Egypt attained at this time a remarkable organization in everything: the written language was formed, the architecture perfected in execution, the religion of sun-worship established, and political matters diplomatically conducted.[3] Harpists, poets, singers, prophets, acrobats, dancers and scribes make their appearance. The drama of Osiris is born, and will later exercise a total transformation of the Egyptian religion. We do not know from which historical

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[1] The name of Menes, the founder of Memphis (*Men-Nefer*), is placed at the head of the royal lists of dynasties at Saqqarah, Thebes, and in the papyrus of Turin; but we have not proofs from monuments. The existence of King Atahuti, son and successor of Menes, to whom is attributed the authorship of some works on anatomy, is less enigmatic. The existence of Ouanephs, successor of Atahuti II, as the builder of the Ka-chemi pyramid, is historically proven.

[2] "No one can possibly examine the interior of the great pyramid," says Mr. Ferguson, "without being struck with astonishment at the wonderful mechanical skill displayed in its construction. The immense blocks of granite brought from Syêné, a distance of 500 miles, polished like glass, and so fitted that the joints can scarcely be detected. Nothing can be more wonderful than the extraordinary amount of knowledge displayed in the construction of the discharging chambers over the roof of the principal apartment in the alignment of the sloping galleries, in the provision of ventilating shafts, and in all the wonderful contrivances of the structure. . . . Nothing more perfect mechanically has ever been erected since that time."—*History of Archit., Vol. i. pp. 91, 92.*

[3] The Egyptian name of the pyramids was Ben-Ben and also Berber (with the interchange of the letters *n* and *r*). Ben-Ben signifies "splendid," from the root *ben* (*Denkmäler*, ii, 43 d) "delight, enthusiasm." Then, must we perhaps see in the Greek πυραμις *per-am*, "house of light." Besides these generic names, the pyramids have been designated by a multitude of rhetorical images, like *sep*, "head, summit," etc. The great pyramid Khufu's was called *Xu-t*, "the horizon," that of Chefrem was called *Ur*, "great," and the third small pyramid of Menkaura, *Har*, "the superior."

event the Osiris myth sprang (though, whenever we see a legend, we may be sure that it is based on some historical allusion); we know only that Osiris was aknowledged as a deity in the reign of Menkaura of the IVth Dynasty. We find in this monarch's coffin[1] the following prayer: "*Oh, Osiris! King of Upper and Lower Egypt, Menkaura! Ever-living, born of Nut, Essence of Seb. Thy Mother Nut is protecting Thee: She granteth Thee Divinity and destroyeth Thy Enemies, Oh King Menkaura! Living forever!*"

A complete religious transformation begins with the apparition of this God: nay! a complete philosophical transformation. Has not the legend always been the parent of æsthetic meditation? Would the sublime poem of Job exist, and Goethe's masterpiece, "Faust," if they had not legends for their origin? The old Egyptian legend is the terrible struggle between Osiris the God of life, or *Un-nefer*,[1] the "Excellent-being," and his brother Typhon or Set, the God of gloom and darkness.

The sombre drama of Un-nefer took place, according to the later tradition, at the fabulous period when the Gods Ptah, Ra and Seb reigned over Egypt. Seb was succeeded by Osiris and his wife Isis. Then came Set, the brother and rival of Osiris, and the terrible duel began between them. Set was victorious and killed his brother. Lastly came Har, or Horus, the orphan avenger of his father and the conquerer of Set. According to the Egyptian mythology, these deities reigned 13,900 years.

Since Set committed this crime,[2] peace and happiness disappeared from the world, to give place to physical and moral evil. The most ancient hieroglyphic texts give us a full account of this dramatic event, and the scribe neglected nothing to acquaint us with the agonized lamentations of Isis and Nephtys "the two divine sisters." A papyrus found in the ruins of Thebes[3] in the interior of a statue representing Osiris, contains an Egyptian jeremiad, and I take pleasure in giving you some fragments of it:

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[1] In Egyptian *un* "to be; being," and *nefer* "good, beautiful."

[2] According to Plutarch (on Isis and Osiris, chap. 13) the tragic death of Osiris occurred on the seventeenth day of the Egyptian month *Athyr*; see my article in the *Melitz* of St. Petersburg, 1886, No. 71.

[3] Now at the Royal Museum of Berlin, numbered 1425. We give here only selected fragments of this long and touching elegy; see Dr. Brugsch's "*Adonisklage und das Linoslied*," 1852. The copy of it belongs to the new Empire.

"SUPPLICATION BY ISIS.

She says:

"Come to thy abode, return to thy dwelling!
—Thine enemies are no more,
Oh beautiful prince! Come, come to thy abode.
Look at me: I am thy sister who loveth thee. Do not stay far from me, Oh Superb Youth!
—Alas! I see no more thy face. My heart is filled with woe on account of thee.
Mine eyes seek thee vainly.
—Shall it be long before I see thee? (bis.)
Beholding thee is happiness. (bis.)
—Come to thy Sister, come to thy wife. (bis.)
—Do not separate from me.
Gods and men look upon thee with tears.
They all sigh for thee when they behold me.
I call thee in elegies to the heights of heaven, and thou hearest not my voice.
I am thy Sister who loveth thee on earth;
No one else hath loved thee more than I,
Thy Sister! Thy Sister!"

This fight between rival brothers was inevitable from the beginning of creation: the world having for maker a Good God, it is natural that the God of Evil should declare himself an enemy of the whole creation. Jehovah found himself, many centuries later, in the same situation when confronted by Satan. The mischievous intentions of the Biblical Satan are directed against mankind only, while the Egyptian Satan, Set,[1] desires a complete annihilation of the whole creation; he prefers chaos to the universe, and darkness to light.

This mystic and everlasting war does but symbolize the strange situation forced on humanity during its short transit on earth, or, rather, it symbolizes the question of physical and moral evil imposed on man. The theologians of the land of the Pharaohs have gone farther with their symbolic sentiments: they have compared God to the "nursing Nile," and the bad spirit to the desert which invades Egypt with its ardent billows. Thus, God's war

[1] Set was selected, during the rule of the Hyksas (shepherd kings), as the sole national deity, to the exclusion of any other Egyptian gods. King Seti, of the 19th Dynasty, paid an unusual homage in adopting his name. Set became finally unpopular. His worship ceased at once, and his name was suppressed from the monuments.

against the bad Spirit becomes a duel between the Nile and the Desert[1].

This philosophical conception of religion, if I may so express myself, has its basis on the legend of Osiris, who appears for the first time at the IVth Memphite Dynasty, about 4,000 years before Christ. At this time the chapters or the rolls of *The Book of the Dead* were yet unknown. The Deity had not yet a distinct name, but was simply represented by the dog-headed Anpu or Anubis, whence sprang, later, the Greek mythological dog Cerberus. Anpu was considered as the Watch-dog of the tomb, as were the Cherubim (Watch-bulls) at the door of paradise, and like the Assyrian Kerebu (bulls) which were the symbolical guardians of the royal palaces of Nineveh[2]. At the most ancient tombs of Memphis, those of Amten and Tee, the invocations are addressed to Anubis alone, while the great procession of myths is yet in its cradle. It becomes powerful in the XIth Dynasty, when the tender Isis appears as a Goddess, and with her comes the birth of the Beautiful, in letters and Art.[3] The famous maxim of a French magistrate, "Cherchez la femme," may be applied to the domestic arrangements of the Gods: the Woman or the Goddess has influenced lofty sentiments wherever she has appeared. (What a pity that the jealous Jehovah was not kind enough to introduce this element into his heavenly court! What a charm would have been added to the books of Isaiah, Job, Psalms, Solomon's love-song, etc., if we had had the intervention of a gracious Goddess in these great symphonies of human thought![4])

Pardon this little digression; and now let us go back to the Vth Dynasty. We find the original worship of the Sun developed and connected with that of many other deities.

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[1] G. Maspero, *Histoire Ancienne des Peuples de l' Orient.*

[2] See my pamphlet, "*Le Schéol des Hébreux,*" p. 12.

[3] The Museum of Boulaq possesses of this dynasty, stelas, vases, clothes, furniture, arms, etc.

[4] The Hebrew language has no name for "goddess." The modern Hebrew writers generally use for goddess *bath ha-shamaïm*, "celestial daughter." The proper Hebrew expression would be, *benath ha-Elohim*, "the daughters of Elohim," thus contrasting with the *sons* of Elohim, mentioned in Genesis vi., 2, and Job ii, 1.

The Supreme Gods Amon "the Invisible," and Xeper "the Self-produced," become identified with the Sun by new theologians. Philosophical humanity is then born with the Prince-philosopher Ptah-hotep, who lived at this time. Antiquity has transmitted to us the moral precepts that Ptah-hotep wrote when he was 110 years old (*Papyrus Prisse*).

Permit me to quote some of his sentences, written about thirty-three centuries before Chirst—

"Be encouraged by knowledge. Reason with the ignorant as well as with learned men."

"The son who accepts the advice of his father will grow old, because obedience emanates from God and disobedience is condemned by God."

"The heart is the Sovereign of man, as regards obedience and disobedience, but still man is free to form his heart by obedience."

"Wash away the impurity of thy mouth, and conform thyself to the precepts of the Lord."

"Happy is the man who honors his father, from whom he sprung."

"Blessed is he who fulfils his father's commands, for a good son is cherished by God."

The old prince finishes with an autobiographical notice:

"I am now one of the oldest men in my country; having passed my 110th year of life, thanks to my august sovereign, and his court, whom I have faithfully served; and hence I merited his goodness."

One might suppose these sentences were detached from a chapter of Wisdom, preached by King Solomon, who lived about seventeen centuries later.

Not only did philosophy flourish, at this time, but all the other branches of cultivated thought. Even the Turquoise mines of King Snefru, of the IVth Dynasty, were skilfully worked by his successors, the Kings Sahura, Raenuser and Menkaura, as appears by the late discoveries at Wadi-Magarah. As for architecture and the fine arts, we have from this early period (the IVth and Vth Dynasties), the pyramids of Gizeh, that of Abousir, the statue of Chefren,[1] founder of the second pyramid, besides the

[1]Shafra (others read *Xafra*) or Chephrem means "born of the sun *Sha - f - ra*," (born of the sun) like the names of the King Ramessu, of the 19th Dynasty. Other Egyptologists translate generally "Ra is his sunrise" (*Xa*), without considering the important point that "sunrise" does not occur *at all* in the names of the Old Empire, and even the names Ra-Sha-Xeper and Ra-Sha-Khau signify probably, "Ra, producer of the universe," and "Ra, producer of beings."

splendid tombs at Saqqarah and at the pyramids. We have also, from this period, a magnificent temple, built of alabaster and granite, discovered by Mariette-Bey at the feet of the Great Sphinx; an inscription of Xufu,[1] founder of the first pyramid; a handsome wooden statue, representing a private citizen; a fine sarcophagus of granite (of the IVth Dynasty); and fifty monolith-stela, statues, etc., which are now to be seen in the Museum of Boulaq.[2]

Egyptian fine arts undergo a slight decadence at the time of the VIth Dynasty: neither temples nor other monuments were built: but on the other hand, the Hydra of war makes its first appearance.[3] We possess a tolerably long inscription, from this period, by a General called "*Una*." He entered the court of King Teta, first as a Prophet-priest, and later became Royal scribe or Secretary of State under King Merienra (Pepa), and finally rose to the rank of General, as he tells us himself.[4] He carried on a campaign against the "*Amu*" tribes (perhaps the *Emim* of the Bible), some of the Asiatic neighbors of the Egyptians, and against the *Herusha* people. He concentrated an army of the *Nahsi* (negroes) from the Ethiopian lands, and made with them several incursions against the *Herusha*. Remark here the very important fact that negroes make their appearance in history for the first time.

Una attacked the enemy, burned their forts, destroyed the vines and fig trees, killed a good many of their people, and finally forced them to submit. But this submission not being complete, Una was again compelled to concentrate another army and to defeat them again. He was highly rewarded for his military services, and this reward from his King was that he was not obliged to take off

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[1] Many explanations have been given of the name of Khufu; I think that it is either the old root *Xef*, "name, title;" or *Khep*, "to erect," then "the erecter." The eldest son of Noah was equally named Shem, "name."

[2] Mariette's *Résumé of Monumental Authorities*.

[3] It is true that we have already mentioned conquests at the IVth Dynasty, on a tablet found at the mouth of the ancient *Makfa* mine: King Snefru is represented there conquering some tribes of the East; but *war* is not mentioned before the VIth Dynasty.

[4] Inscription found by Mariette and placed in the Museum of Boulaq. A partial translation was given, first by de Rougé, in his *Rechèrches sur les Monuments: Les Six Premières Dynasties*, Paris, p. 117. The entire translation of Una's inscription is given by S. Birch (*Record of the Past*), Vol. ii, pp. 3–8.

his sandals when he entered the royal palace. Una adds with proud satisfaction (line 35), "Never before was such an honor accorded to any other official."

Let us do justice to the gallant Egyptian officer, in stating that his record contains but little of the element called *chauvinism*, or *jingoism*. He speaks rather as an impartial historian than as an officer. What a difference between his record and the annals of King Thotmes III, of the 18th Dynasty, who exhausted in his vocabulary every sanguinary and blood-thirsty expression to qualify his victories![1] The reason for this may be because Una began his career as a priest, and did not receive an early education in barracks, which often robs a man of the gentler experiences of life.

At this early period, Poetry had not been prostituted to sing the savage scenes of human butchery. War was not yet glorified, as it was a few centuries later. Like our truly civilized selves, the subjects of Pharaoh, had the same fanaticism—that most awful scourge of humanity—the belief that their own country was superior to the whole earth, and that citizenship overshadowed fellowship. All that was not from Ta-meri, "the beloved country," was irrevocably condemned. After all, why should not the nation of Xam have had her "Out of Egypt there is no salvation," as well as other nations, which, urged by that strange but universal sentiment of selfishness, have proclaimed that they were *the* "elect?" Did not wise Greece adopt this same prejudice? Did not ancient Rome term those "barbarians" who had not been favored by fate in having been born on the blessed soil of Jupiter? And that nomadic people of Canaan, the future nation of Israel; did they not contract an irrevocable alliance with God, to the exclusion of all the other nations of the globe, because these latter invoked their Creator under various names of Baal, Kamosh, Dagon, Ashtaroth, Ptah, Ra and Osiris, instead of designating him by the autocratic name of Jehovah? Thus we have had everlasting wars, fought on account of trifling synonyms. We must not be surprised, then, if the river Nile has, in ancient times,

[1] Tablet of Thotmes, found at Thebes, in the Karnac quarter. This extraordinary tablet was published first in the *Archæologia*, Vol. xxiii, p. 373, and afterwards translated by the Vicomte de Rougé, *Revue Archéologique*, 1861, p. 196.

resounded with war songs as wicked as those heard to-day in civilized Europe. The famous song of Thotmes III, the records of Rameses II (the Sesostris of the Greek writers) their strange chauvinism, as marked on the New York obelisk[1] and elsewhere, may serve as a prototype of the future "*Marseillaise;*" "*Wacht am Rhein*" and other poetic (!) inspirations of this kind, with their horrible mission, "to glorify crime."

No, no! Poetry has nothing to do with the miserable jingle of sanguinary and homicidal strophes; poesy does not inspire them, as she never inspired criminal hymns, the ancient Phœnicians sang, with pious enthusiasm, to their horrible Moloch, while they immolated to him rosy babes. It is unfortunately true that the modern Moloch—Mars—has, like his antique Phœnician prototype, his temple, his priests, his adorers, and, especially, his innumerable victims. But he has no poets; the Muses and the Furies never can be sisters.

But if the Egyptians had, like ourselves, laws whereby crime was permitted, encouraged, sung and glorified, legitimate indignation never has ceased to protest energetically against them by the mouth of wise men like King Amen-em-hat. We have already quoted some philosophical sentences from Ptah-hotep; let us now see what is King Amen-em-hat's opinion about war. This monarch (he would be termed to-day, by newspapers, a "bombastic monopolist"), who reigned in the XIIth Dynasty, left a testament to his son, Usertasen I, wherein he explained how he had once been obliged to fight "because he was miserably assaulted."[2] He says (line 3):

"Rely on thyself, Oh, my heart, because man has no friends in the day of misfortune. However, as for myself, I have assisted the helpless and strengthened the powerless. I have granted assistance to him who wanted it and to him who already had it."

Line 5th is very touching; he says, with pride, that he has prevented war, and deplores bitterly the fact that man, as oblivious as a bull, likes always to recommence fighting, in spite of the terrible consequences which he has already experienced.

"*My image will be durable among men because I have suppressed*

[1] The New York obelisk belongs to the period of Renaissance.

[2] Papyr. Sallier ii, pl. I, 1.—I, pl. III, 19. It is dated by the Scribe Enna-Enna: the first year, second month of Pert, day 20th.

the cries of the afflicted. No more battle-fields! Wonderful to say that fighting ever took place before (I suppressed it), *Oh bull forgetful of yesterday!*"[1]

To this old Empire is to be attributed the formation of temples and colleges in Thebes and Memphis as well as the celebrated university at "*On*" (Heliopolis), where was built Egypt's first *temple* and theological college. "*On*" is now a miserable village called Metarieh, five miles from Cairo). The art of embalming was taught as well as anatomy. Dissertations on theological subjects, and on religious philosophy (everything being connected with religion), were debated; such as, "*Invisibility*" (Amon)[2] and "*Self-production*" of the Supreme being (Xeper), as well as regards the immortality of the soul. The soul was supposed to emanate from the Sun and appeared after death before Osiris, the judge of the dead, who was assisted by the forty-two assessors in the hall of Truth and Justice. But besides this ultra-terrestrial justice, the Egyptians were provided with laws punishing crime and offences. Murder, theft, adultery and demonolatry were punished by decapitation.

We must not be too much surprised at the severity of judgment regarding adultery. The gentler sex of the Nile Valley were not models of female virtue, if the Egyptian women were really as they

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[1] M. Maspero (*Records of the Past*, vol. II, p. 12) translates this difficult passage: "And yet it had been fought before (as if the land were) a bull forgetful of yesterday," which is not clear, even with its hypothetical restitution. The translation I propose without restitution, is also justified by the papyrus text, and gives a satisfactory sense: "O bull forgetful," referred to man, cf. Isaiah 1, 3, where we find the same rhetorical image.

[2] Originally, *Amon* was not identified with *Ra*, and the union of the two divinities took place about the 18th Dynasty; thenceforth *Amon* was worshipped as *Amon-Ra*. Bunsen, *Egypt's Place in Universal History*, vol. i, p. 371; *Records of the Past*, vol. ii, pp. 20, 31, 34, etc.; Rawlinson, *Hist. of Eg.*, vol. i, p. 325. *Ra* was adored at On, called by the Greeks *Heliopolis*, "the city of the sun," and at Thebes he was identified with *Amon* and adored as *Amon-Ra*; at Memphis he was united with *Ptah* and *Pasht*.

Amen means in Egyptian "to conceal, to hide;" hence comes the mysterious place called *Amenthys* or *Amenti*, which corresponds to the Greek Ἅιδης and the Latin *Orcus*. Plutarch explains in his *de Isis et Osiris*, Chap. 29, that Ἀμένθης means ὁ λαμβάνων καὶ διδους. This explanation is probably based on the Coptic words *Amoni* (to take), and *Tï* (to give). Plutarch has ignored the fact that the real etymology of *amenthys* is Ἀμοῦν τὸ κεκρυμμένον.

are depicted in some hieroglyphic romances and in historical texts. The female education was concentrated on music, and on the fine arts only; science and letters were ever considered useless for women, whose only mission on earth consisted in the art of pleasing and in nothing else. But we must not conclude, therefore, that the Egyptian women were considered as instruments of pleasure alone, as they are in the barbarous conception of Islam. The Egyptian lady was never secluded in a harem, but she enjoyed equal rights with her husband before the law. The dress of both sexes was nearly the same; gold collars, chains, bracelets, anklets and rings were worn by each; the ladies appropriating ear-rings to their own sole use.[1]

Leather and papyrus sandals began to be used in the Vth Dynasty; linen garments had been worn long before.

Pharaoh himself, was not considered, as many historians have thought, an autocrat, a kind of Czar, because he was nearly always assisted by Ministers, Royal scribes or Secretaries of State, Counsellors, and others, who formed a kind of *House of Lords.* In the army, we find Generals (hautu), Captains (menh-u), and lieutenants (ten-u). The Monarch was head of the army.

The Egyptians were fond of smybols and mystical allegories which always had a profound signification whether in a philosophical point of view, or from a high poetical standpoint. Thus the obelisk represents the mysterious and divine power of reproduction.[2] Even to this day, the same symbolical idea has been adopted by nearly all the nations of the world; we have only to glance at a church steeple to be convinced that the tower reproduces the shaft of the obelisk and the steeple the pyramidion.

The obelisk is also, to-day, the most common form of sepultural monument, symbolizing re-production,—re-creation.

As for the Sphinx, I think it a very high artistic conception. Imagine what high power and what inspired sentiments the artist must have had, who discovered how to combine together physical and intellectual force![3] The body of a lion and the head of a man. The strength and majestic aspect of the

[1] Cf. Birch's *Ancient History*, Vol. i, p. 15.

[2] The Egyptian word for obelisk is *teken*.

[3] Clemens, of Alexandria, says the Sphinx symbolized *αλκή μετὰ συνὲσεως* "power with insight." The Egyptian names for Sphinx are *Xu* and *S-seps.*

graceful animal combined with intelligence, love and purity. Have you ever seen in any museum the smiling melancholy of a Sphinx? He seems to say in his ancient language:

> "*Sa ret, her-a peter*
> "*Au-a en neferu Xeper!*"
> "Son of man look on me!
> "I am the form of beauty."[1]

To this old Empire can be attributed the magnificent Hymn to Amon-Ra. There is no doubt, but that the handwriting of this hymn belongs to the 18th Dynasty, a short time before Joseph, the young Hebrew, came into Egypt; but the manuscript[2] says at the end of it, that "it is a copy of one of the oldest books that had been *discovered;*" and the Egyptians regarded it at this early time, as we regard to-day the poems of Homer—as a song of the ancients. By its archaic phraseology, too, we can refer it to the old Empire.

I will read you four strophes of this remarkable poem, which I have translated for this occasion—

Verse 3. Amon-Ra, superior of all the gods!
Thy goodness brings the gods to ecstasy
And they pay adoration to thee in the sanctuary.
Oh, thou who art crowned in the house of flame!
The gods love thy brilliant apparition
When thou comest from Arabia,
When thou sailest, O, prince of dew,
Through foreign lands to appear gloriously
In the divine region of Palestine.

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[1] The Great Sphinx is called *Har-ma-Xu* on the granite tablet of Thotmes IV, of the 18th Dynasty, where the legend says "it grants power and pure life to the King."

The Great Sphinx, says G. Rawlinson, must be admitted to be a striking monument, and to impress the spectator, not only by its bulk, but by its air of impassive dignity. (*History of Eg.*, vol. i, p. 269.) But a charming description of it has been given by Ampère (quoted by Rawlinson, *loc. cit.*); "Cette grand figure mutilée est d'un effet prodigieux; c'est comme une apparition eternelle. Le fantôme de pierre paraît attentif; on dirait qu'il entend et qu'il regarde. Sa grande oreille semble recueillir les bruits du passé . . . Sur cette figure, moitié statue, moitié montagne, on decouvre une majesté singulière, une grande sérénité, et même une certaine douceur."

[2] A fac-simile of this hieratic papyrus (numbered 17 in the Boulaq collection) has been published by Mariette: *Les Papyrus Égyptiens du Musée de Boulaq.* fo. Paris, 1872. pl. II, 13. The manuscript is perfect from beginning to end, and has been commented by M. Goodwin, Grébant and myself.

7. The gods rush to his feet
To acknowledge his Majesty as master,
As lord of terror and grandeur.
(They say to him): "O Lord of spirits![1] powerful!
Bringer of gifts, maker of presents!
Salutation to thee, Creator of the gods!
Thou hast suspended the heavens,[2]
Thou hast laid down the foundations of the earth.[3]

8. Thou consolest[4] those oppressed by the tyrant.
Thou renderest justice to the poor and the martyr.
O! thou art Lord of righteousness because thy precepts are right.
The Nile overflows by thy will,[5]
(*Because thou art*) Lord of tenderness and love.
Thy rising brings life to men,
Thy apparition opens their eyes.
Thou actest also in the immensity of the sea.[6]
Distributor of delight and light!
The gods glorify his goodness.

13. Homage to thee, say all the creatures;[7]
Adoration to thee from all the regions;
From the height of heaven to the space of earth,
To the deep of the incommensurable sea.[8]
(Even there) the gods adore thy majesty.
The spirits thou hast produced praise
With joyful hymns their Maker.

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[1] *Ur ba-u*, "chief of spirits." Moses applies the same epithet (*el elohe ha-ruchoth*) tanju in one of his prayers to Jehovah, which has no hebraic physiognomy. Moses, the adopted son of Rameses II, must have known this beautiful Egyptian hymn. Numbers, Chap. xvii, 22.

[2] *ax pet* corresponds literally to *nata shamaïm* of the celebrated psalm civ, 2.

[3] The Egyptian word for "earth" here is not *ta*, but *satu*, "the deformed earth," a very archaic form. The same image is employed (*beïasdi ares*) by Jehovah, apostrophizing Job (xxxviii, 3).

[4] *Naâm*, or *naham*, "to alleviate," or "to console," and not "to deliver," as usually translated. *Naham* is a Shemitic word.

[5] See Ps. civ, 7–11.

[6] *Nu* designates, the abyss, as the Hebrew word *thehom*, and sometimes also, "the great ocean."

[7] Literally, "said by all the creatures" (*t'at en aut neb-u*).

[8] *Matui nat ur mer.*

> They exclaim: come in peace[1]
> Father of the fathers of all the gods,
> Who supportest the heavens,
> Who layest down the foundation of the earth![2]

The study of the antique Egyptian language is now well cultivated; it has already dictionaries, grammars, poetic treatises, periodicals and societies.[3] Egyptian is taught to-day in many of the universities of Europe by Egyptologists of renown. The United States is represented by many of them. I will mention here two only, because they are both living in Philadelphia, Admiral McCauley and Prof. J. P. Lesley. The first is the author of a *Dictionary of Egyptian Hieroglyphics*, published in the *Transactions of the Philosophical Society*, and has still some other valuable manuscripts on the favorite subject he cultivated when between sky and sea.

Prof. J. P. Lesley, amidst his geological and philosophical studies, has endowed Egyptian archæology with valuable dissertations by commenting learnedly on hieroglyphic texts. I desire to acknowledge my indebtedness to these Egyptologists of your city, who have kindly facilitated my task by the loan of scientific books and by their artistic taste. Nor should I finish without expressing my thanks to Dr. Frazer, of Philadelphia, who was good enough to introduce me so kindly before this select audience. The Doctor, who introduced me was right, when he said: "The FRANKLIN INSTITUTE is a great depôt of patents, and not until the last obelisk is deciphered, will we be certain of priority in telephones and steam

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[1] *Aiui em hotep*, "come in peace," or welcome; an expression corresponding with the Hebrew *boi beshalom* (come in peace), and to the Arabic *ahlan washahlan!*

[2] I have translated some fragments of this beautiful hymn into Hebrew verses, with a short commentary, in the *Melitz* of St. Petersburg, 1887, No. 37.

[3] See Champollion, *Grammaire Egyptienne*, Paris, 1836; *Dictionnaire Egyptien*, Paris, 1841; Lepsius, *Lettre à M. Rosellini sur le système hièroglyphique*, Rome, 1837; Birch, *Egyptian Grammar and Dictionary* in Bunsen's *Egypt*, vol. v; Brugsh, *Scriptura Ægyptiorum Demotica*, Berlin, 1856; *Hieroglyphisch-demotisches Wörterbuch*, Leipsic, 1868; De Rougé, *Grammaire Egyptienne*, Paris, 1867; Maspero, *Sur les pronoms et les conjugaisons, en egyptien et en copte;* Rawlinson, *Language and Writing*, vol. i, chap. iv, of his *History of Ancient Egypt*, London, 1881, Admiral McCauley, *Dictionary of Egyptian Hieroglyphics*, Philadelphia, *Trans. Am. Ph. Soc.* 1883, etc.)

engines." Nay, the centuries which built such gigantic artificial mounds, the pyramids of Gizeh ; the people who, in the immemorial period of the first dynasties, cultivated anatomy and invented the art of embalming ; the thinkers who have borne so high the the standard of artistic sentiment ; such a people is capable of everything ! Thanks to the French archæologist, Champollion, the first interpreter of the Egyptian Past ; we have only to question the venerable ruins of the old Misraïm to make acquaintance with generations which have disappeared seventy centuries ago ! We will never be certain of priority of thought in philosophy and æsthetics, until we reveal the remainder of the grand pages of civilization's first appearance ;—until we find the first historical lines traced by a dawning humanity !

APPENDIX.

The want of Egyptian types in this city prevents the author from giving here an alphabetical explanation of all the words he employed in his Egyptian dialogue. But apart from this, an explanatory lexicon would be of no use for those readers who are not acquainted with the hieroglyphic writing, and superfluous for Egyptologists, who have but to take any Egyptian dictionary to find every word used in the dialogue, in its right place : the author having avoided, as far as possible, forced or arbitrary significance, notwithstanding the modern physiognomy of the subject.

This specimen of Egyptian literature being the *first* attempt to write in ancient Egyptian, the author leaves it to the judgment of philologists.

I have written the following Dialogue in the old Egyptian language with a translation, in order to show you that Egyptological studies are very progressive, since we are able to render in Egyptian even modern thoughts. The words I have used here are gathered from all periods.

ELECTRIC WELDING.

By Elihu Thomson.

[*A Paper read at the Stated Meeting of the* Franklin Institute, *held Wednesday, March 16, 1887.*]

Ten years ago I had the pleasure of giving a course of five lectures on electricity in the hall of the Franklin Institute, as part of the winter courses, and the leading idea I presented to my hearers was, that electricity from whatever source, and however manifested, is always of the same nature, and differs from that produced in other ways in its tension or potential, which is analogous to pressure in fluids, and in volume or amount of current, which is analogous to rate of flow of fluid or to the quantity moving in a pipe or conduit past a given position in a definite time.

Among the experimental demonstrations used to support this view, were some which were made with an ordinary induction coil, such as is commonly employed to obtain from low potential battery currents, high potential discharges through air, resembling lightning, or what is often called static electricity, such as is employed in the charging of leyden jars, etc.

After showing the induction coil as so used, I reversed the process and passed high potential discharges from a charged battery of leyden jars, through the fine wire coils of the induction coil, and received currents of low potential but of great volume from the coarse wire of the coil. By putting a low resistance galvanometer in the circuit of the coarse wire, known ordinarily as the primary, a strong deflection of the index of the galvanometer took place, and upon bringing the ends of the coarse wire coil together in slight contact, a bright green flash took place at every leyden jar discharge through the fine wire. While repeating this instructive experiment, showing the indentity of electricity and the reversibility of the induction coil, I noticed at one time that after the discharge the ends of the wire of the primary or coarse coil had stuck rather firmly together, and it then occurred to me that possibly metal wires might be united by properly organizing the appliances. My attention was turned, however, to the field of electric lighting, in the development of which field I have, since 1879, been almost

exclusively engaged. Some four or five years ago the need of a quick and effective method of joining together the ends of copper and other wires, as in the construction of our dynamo machines and other electric apparatus, presented itself. The joints, as ordinarily made, were formed by tapering each end and soldering or brazing them together sidewise, and the joints were of clumsy and uncertain character, unless made with great care; and, moreover, destroyed the flexibility of the wire at the joint.

It was at that time difficult for us to get wire of any considerable length in one piece, and as some of our dynamo coils contained about 300 pounds of copper wire, the making of several joints in the coil was unavoidable. My old experiments for the INSTITUTE lectures recurred to me, and I designed an apparatus for welding the ends of the wires together. This apparatus was constructed on the first opportunity, and far greater success was obtained with it than had at first been anticipated. What the results are will presently appear.

Larger and better apparatus was then constructed, and larger work accomplished, and I now see no reason why it would not be possible to construct machines for electric welding, which would work upon pieces a square foot or more in section, and am inclined to think that such work can be economically done.

It will be convenient to consider, (1) the source of electric current; (2) the means for applying the current to the pieces for welding; and (3) the welding operation itself.

It is believed that any electric current generator capable of giving volume of current depending on the sizes and nature of the metal pieces to be welded and of a low potential, or, at least, of low potential between the connections on each side of the joint to be made, will be suitable. As examples of such sources may be mentioned batteries of very low resistance, such as storage cells of large size, or a number of smaller cells coupled together in multiple, so as to combine their currents; dynamo electric machines giving either alternating or continuous currents, of large volume. Special designs of such machines are being constructed for the work. Another source of current and a convenient one, is a properly organized induction coil, or, as now often termed, a transformer or converter, taking alternating currents of comparatively high potential and small volume from a line connected with an

alternating current dynamo, and giving out currents of low potential and great volume, at the place where the work is to be done and where the induction coil exists. The principle of action and, in fact, the essential elements of the induction coil so used, in so far as the production of currents of low potential and of great volume, from currents of high potential and small volume is concerned, may be found in the reversed action of the induction or Ruhmkorff coil, shown in 1877, and before referred to. In the apparatus there are found two coils or conductors, placed parallel and near together upon an iron wire, or sheet-iron core, or in a laminated or divided iron sheath.

The coil or conductor which receives the high potential or high electro-motive force current is of comparatively small sized wire and of many turns, while that which furnishes the heavy welding current is of much larger section, or is composed of a strand or bundle of wires of few turns and of very low resistance, so that the large currents may freely circulate.

Whatever source of current be used, it is desirable to have the apparatus so controlled that the energy of the current may be adapted to the size and nature of the work to be done. Thus if a battery be used, a switch for putting on or taking off the current should be placed in its circuit and, where the power of the battery is to be applied to varying sizes of work, a variable resistance may also be put into its circuit, or the plates or cells of the battery may be used in sets, the number of plates or cells in a set being varied by a sliding switch. This arrangement is indicated in *Fig. 1*, where S, S^2 and S^3 are cells, one terminal of each being joined to clamp C, and the others left free, but capable of being connected with the clamp C^1, by a movement of the switch S, so that one or more cells in multiple may be in operation. The pieces in place for welding are represented by B and B^1. It would sometimes be convenient to have means of immersing the plates of the battery in the liquid to varying extents under control of the operator. These are all well known ways of controlling the available energy of either ordinary chemical batteries or of storage batteries.

Concerning the means for applying the current to the pieces to be welded, it may be premised that they are subject to considerable variations depending chiefly upon the forms and materials of the pieces. Generally clamps of heavy copper are provided so

that the pieces may be securely gripped and then abutted at the place where the weld is to be made. The clamping surfaces are best when shaped to the configuration of the pieces, or nearly

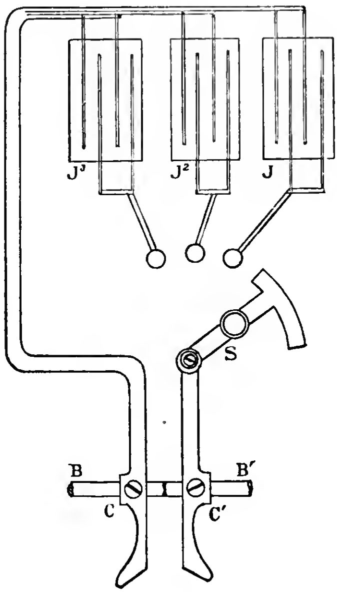


FIG. 1.

thereto, though the ease with which even flat clamping jaws may be used on curved or irregular work is remarkable. The clamps are, of course, kept insulated from each other except that they are connected with the terminals of the source of currents. While usually

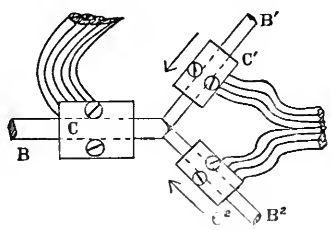


FIG. 2.

but two clamps are needed, the simultaneous joining of three or more pieces, as in making a fork by a common weld of three ends of pieces, is best done with a like number of clamps, *C*, C^1, C^2, *Fig. 2*, one

holding each piece with the current divided and distributed between the clamps. In the case of two clamps only being used, which is the common condition, either one or both clamps are movable towards and from the other. For most work this movement is in a right line secured by suitable guides, but for welding circular rings or curved pieces, the movement given is better made on a curve corresponding with that of the pieces. These are mechanical details upon which it is needless to dwell.

The force of a spring or of a screw, or even a manual pressure, is used to press the clamps and the pieces held by them together during welding. The amount of pressure used depends on the size and properties of the metal of the pieces. Tool steel requires more pressure than iron, because the weld must be made at comparatively low temperature, to avoid injury to the material. It may be here remarked that the clamps which hold the pieces and pass the current from piece to piece are sometimes fixed in position, when lap welds are to be made and lateral pressure or hammering is applied to force into union the lapping surfaces after the passage of current has heated them to the welding heat or temperature at which they are plastic enough to unite.

However, butt welds can be made electrically of so perfect a character that as applied to joining the ends of bars or plates, lap welding, while more slow and difficult, possesses no advantage in strength.

When the pieces to be united are too short to permit the application of clamps to them, they are simply inserted between blocks which press them together and convey current to them.

A form of apparatus suitable to the welding of wires and small bars is here shown, and it may be described as follows: It is an induction coil, whose iron-wire core, *II*, *Fig. 3*, has been wound over with a coil of primary wire *P*, to be traversed by currents from an alternating current dynamo. The outside coil or the secondary coil *S*, which generates the welding currents by induction from the primary wire, is composed of sixty-four wires in a strand, which makes only a few turns around the core. The ends of the secondary are bolted down to plates *P P'*, upon which the clamps *C C'*, for holding the pieces to be welded are mounted. One of these clamps *C'* is arranged to slide upon its copper bedplate, and is guided so as to move in a line towards the other clamp block, by the elastic force of a spring *Z*. During formation of a

butt weld, the movable clamp is drawn a little towards the other at the moment that the metal of the pieces is hot enough to yield at the abutting point. A cam *K*, is placed so as to be turned to hold

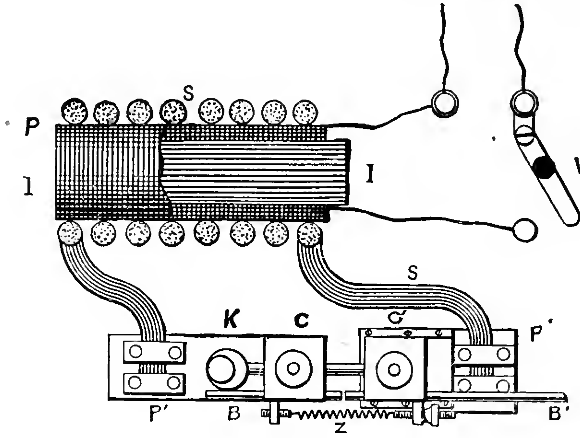


FIG. 3.

the clamps apart during insertion of the pieces in them. The complete apparatus is shown in *Fig. 4*.

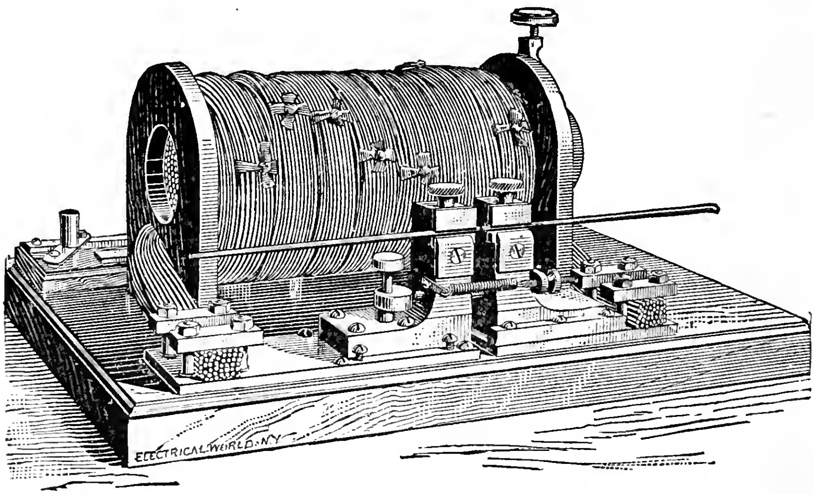


FIG. 4.

The operation of placing the pieces in the clamps is the work of a few seconds only. In this apparatus just described, the part consisting of the primary coil and iron-wire core is movable in and

out of the hollow secondary strand, to vary the power of the induced currents. On account of the short length of conductor in the secondary, *S*, the currents produced in it are of very low electro-motive force and of great volume.

In larger apparatus, such as has been employed for some of the heavier pieces here shown, the construction is different, but

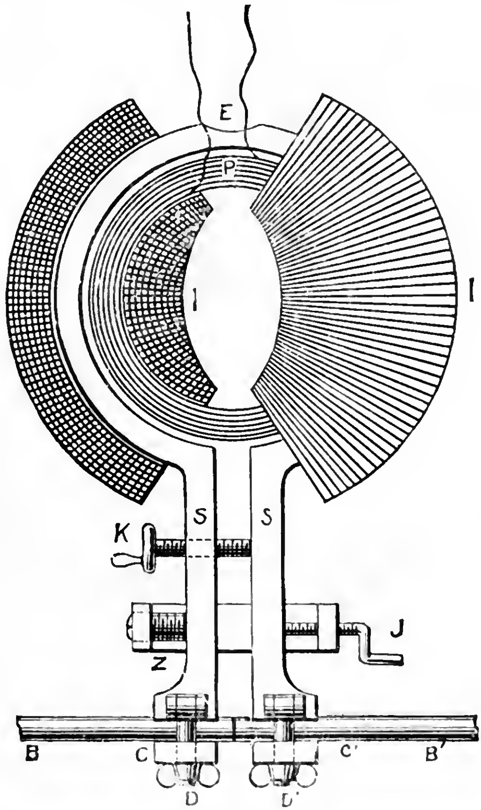


FIG. 5.

depends on the same principles. The primary *P*, *Fig. 5*, is a large, open ring, and is composed of many turns of insulated copper wire. The secondary, *S S*, is simply a single heavy bar of copper bent to make only one turn outside the primary coil, its ends are turned outward, and provided with powerful screw clamps, *C C′*, for holding the pieces, *B B′*, in place and in abutment. The form of the secondary is somewhat like a jews-harp, with the clamps on the

ends of the parallel portion. The bar, S, is thinned at E, and broadened there so as to give a certain flexibility. A powerful screw and spring at $Z\mathcal{J}$, forces the clamps together when the apparatus is used. *Fig. 6* is a view of the larger apparatus complete.

Over both primary and secondary a heavy sheathing of iron wire is wound, forming virtually an endless magnetic circuit of iron around them. The iron wire is wound upon a casing which encloses the two coils, P and S, and prevents the iron wire from interfering with the free movement of the parts of the bar, S, and lamps, $C C'$. The resistance of the secondary bar is about ohm.

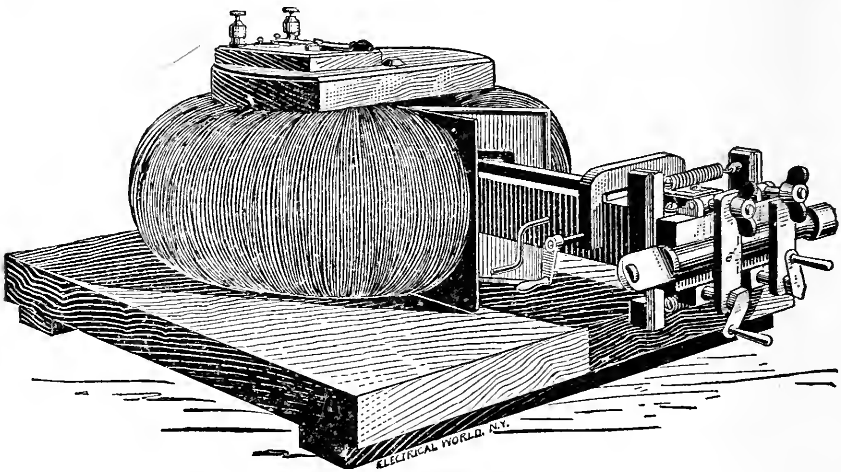


Fig. 6.

Vigorous alternating currents, of comparatively high potential, passing in the primary circuit, P, generate in the bar S, when its circuit is closed by pieces B B' to be welded, a low electro-motive force acting over a circuit of such low resistance and giving rise therein to currents of enormous volume, such as have hitherto been unknown in the electric art. Currents estimated to exceed 25,000 ampères have been present when doing some of the heavier work thus far attempted, and apparatus will soon be completed, which will far exceed this output, and proportionately larger pieces will be welded.

To prepare the pieces for the operation of welding by electric means, all that is necessary to be done is to clean those parts of

the pieces which ... the clamps by filing or emery, and to see that the ends or su...es to be welded are clean enough to effect a contact when pres...d together after placing in the clamps. The shape of the abutted ends matters little, as a joint will be formed even when the ends are irregular, but it is best to have the surfaces either flat, or with the edge chamfered a little, or with one or both surfaces made somewhat convex, in order that the joint may begin in the middle of the abutted section.

The pieces are placed in the clamps, with the ends to be joined projecting therefrom a small amount, and a moderate pressure tending to hold them in abutment, is applied. Sometimes at this stage, a flux, as borax, is added, after which the current is put on. Heating of the abutted ends at once begins and proceeds with a rapidity depending on the current flow, and the size and nature of the pieces treated, reaching the welding heat or temperature of union for the metal, or even reaching the point of actual fusion. With great energy of current, joints on iron-bars of over one-half inch diameter have been made in less than three seconds after applying the current, and with small wires the action is almost instantaneous.

During the passage of the current through the pieces, the pressure given to cause the union may be sufficient to produce more or less of an expansion or swell at the point of juncture, and by adjusting the pressure and temperature, the amount of such expansion may be governed to a nicety. It will also be evident that the temperature to which the pieces are heated, is most perfectly under control when suitable devices are employed to govern the flow of current. As a consequence of this, varieties of steel which are easily injured by excessive heating, or which will not bear hammering when hot, may be welded quite readily. Even very fusible metals, as lead, tin, zinc, may be welded if resin, or tallow, or chloride of zinc be used as a flux instead of borax. It has sometimes been asked, whether the electric current has any specific action in effecting the weld, other than its power to produce heat. It is certainly true that the molecular agitation which is produced by the current, and which manifests itself to us as heat, is more vigorous just at the melting surfaces than elsewhere, and that the current has the property of heating the whole section of metal uniformly by virtue of the fact that any cooler line of particles has, as

a result of being cooler, a less resistance than the hotter portions, and at once receives an undue proportion of the current passing, which, developing heat, soon brings the cooler particles to the same temperature as that of the other parts of the abutted section of the bars.

Very accurate work can, of course, be done when the clamps are kept in perfect line, or when the abutted surfaces are held in correct relative positions during the passage of current.

The results obtained in the application of electric welding to the various metals, promise to be of great practical importance. While ordinarily it has been the exception that metals weld readily, with the electric method no metal or alloy yet tried has failed to unite with pieces of the same metal, and the trials have included most of the metals commonly known—such as wrought iron, mild steel, tool steel; special steels, such as Mushet steel, and even cast-iron joints also being made between these different varieties of iron. Copper and its alloys, brass, bronze, german silver, etc., silver, pure and alloyed, gold, likewise, platinum, zinc, tin, lead, aluminium. The list is being extended as time and facilities permit.

Joints between different metals or alloys are often easily produced if their physical properties are not too unlike. Copper, brass, german silver, steel and iron, can be united one to the other, and in some cases the joints are of remarkable firmness and strength. I will close the present paper with a list of possible extended applications of the process in the arts, which is, of course, subject to extension in the future.

(1.) Joining wires, or bars, end to end, whether round, flat, square or polygonal in form. Under this heading would come making of long lengths of wire for telegraph and telephone line work, and joining small sections of wire into one length as in the construction of electrical apparatus. The specimens exhibited show varieties of such work.

Very large bars of iron or steel may, it is believed, be welded when the power of the apparatus is proportionately increased. The operation is undoubtedly economical of heat, because the heat used, whether obtained from steam or water-power indirectly, is concentrated just where it is needed for the work and is perfectly regulable. With large pieces, a saving of loss of heat by radia-

tion and convection to the air may be effected by applying a covering or shield lined with a non-conductor of heat, and made in sections to fit over and enclose the work, and either resting on it or kept out of contact as the case may be.

Examples of the welding of bars end to end appear in *Fig. 7* which is taken from a photograph of bars of iron, steel, copper, brass, zinc, lead, etc. Some of the bars, *19*, *20* and *21*, have been bent after welding. Bar *2* is composed of iron, copper and brass. Bar *3* is of copper, but has been hammered out flat at the weld.

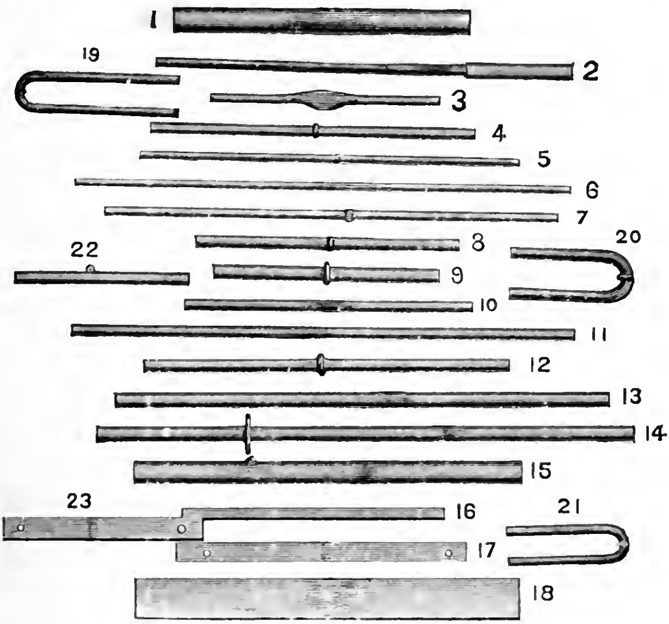


FIG. 7.

Bars *16*, *17*, *18* and *23* are square or rectangular in section. Bar *15* is composed of two pieces of cast iron welded together and the resulting bar in turn welded to a wrought iron piece.

(2.) Tubes and hollow forms of various metal may be welded together with facility, and it would be quite within the bounds of easy practicability to lay welded lines of wrought-iron or mild-steel, or even cast-iron pipe, with few or no screw joints. A small wire may convey the current to the place where the work is to be done, and the induction apparatus may be mounted so as to be portable. As the joining of lead pipes is effected with ease, a

soldered or wiped joint need no longer tax a plumber's skill. With wrought-iron pipe, the joints can be pressed or hammered, while the heat is maintained by the current. The specimens here shown give some idea of the work accomplished. *Fig. 8* represents the appearance presented by tubes of lead, brass, copper and iron in which a butt weld exists. Some of the joints have been hammered during the welding. *No. 1* is a lead pipe bent at *W* after welding.

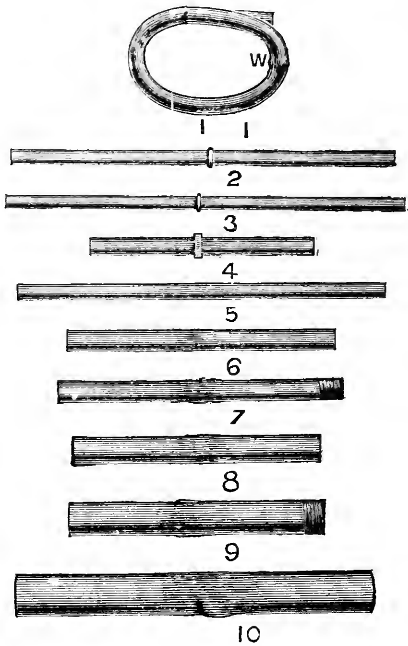


FIG. 8.

(3.) Endless hoops or rings, such as wheel, ties, barrel and tank hoops, band saws, chain links and chain, endless wire cables, etc., may be easily made or mended. Some examples of such work are here shown; one of the most notable of which is a piece of chain, all the links of which have a double electric weld; or, in other words, the links are made of two U-shaped pieces welded together at both ends simultaneously. One of the links is made of such pieces with a central cross-bar inserted and all welded together, the said bar dividing the link at its centre.

(4.) Making and repairing steel and iron, or other metal articles, such as screw bolts, taps, drills, knives and cutting instruments. There is an endless variety of this work, which can be materially assisted or simplified by electric welding. Bolts are lengthened or shortened as desired; taps, drills, augers, bits, reamers, etc., are in like manner lengthened. Poorer steel may be used for the body of a tool, and a better for the portion which forms the cutting edge. Lathe tools, worn or shortened by use, may be pieced out with facility. Different diameters of steel bar can be united readily, so

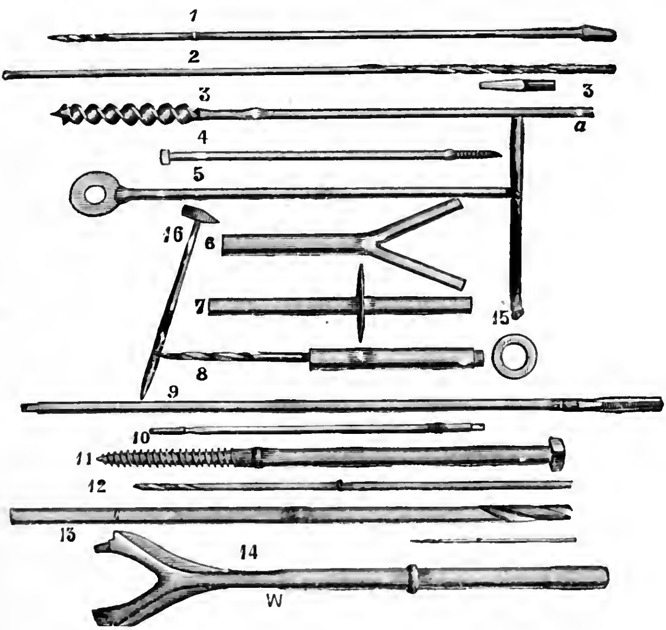


FIG. 9.

as to save forging and save material. Very delicate work, as in jewelry, may be effected. The construction and repair of delicate tools and appliances can be facilitated in many cases.

Fig. 9 is taken from a photograph of pieces typical of tool work. *Nos. 1, 3, 4, 9, 10, 11, 12* and *13*, are tools, as taps, drills, etc., lengthened by insertion of pieces. *No. 5* is a washer welded edgewise to a bar. *No. 6* is a fork composed of three pieces welded. *No. 7* is a steel disc welded in between two bars of iron. *No. 8* is a small twist drill welded to a taper shank of large diameter, the weld being made in the smaller section piece.

Specimens here presented show how readily small work is done, and I may refer to the fact that broken tools are easily mended without in many cases taking them out of their handles. This is instanced in the case of pen-knives, which are provided with new blades welded to the stumps without taking them out of the handle, and though the stumps project out not more than one-eighth inch. As evidence of the strength of the union effected between the pieces, I call attention to the numerous examples in copper, iron, etc., in which the specimens have been violently twisted and bent after welding.

The amount of power demanded for doing the work varies, of course, with the size of the pieces, and also with the material. Wires of less than one-fiftieth inch require very little power to be expended, while to weld bars of iron or steel of two inches in diameter, might require about forty to fifty horse-power to be used in driving the machine, and for a time estimated at a minute to a minute and one-half. This is an estimate only and may be too high.

Where the power at command is limited, a heavy fly-wheel set in motion may be used as a sort of power reservoir, which will, by virtue of its momentum deliver an excess of power for the short time necessary in welding, except when the pieces are of very large size.*

The COMPARATIVE EFFICIENCY of the TEETH of GEARS.

By George B. Grant.

The effect of friction between the teeth of gears is not well understood, and the popular impression, even among educated engineers, concerning the comparative efficiency of the two forms of teeth in common use—the involute and the cycloidal—is that the latter is much the most economical, and, therefore, much better adapted for use for the transmission of heavy power.

This impression is entirely wrong, the reverse of the provable facts, and it is based not entirely on fancy but partly on the teaching of authorities that are undoubtedly competent.

It is with no small feeling of timidity, that I venture to contradict the declared and apparently proved opinions of such high

* [The Committee on Publications is indebted to the *Electrical World* for the use of several of the illustrations accompanying Prof. Thomson's paper. W. H. W.]

authorities as Reuleaux, Herrmann and others, and I would not dare to assert a contrary view if I did not feel able to prove it, by evidence that will bear the closest examination. I will give the demonstration in great detail, so that it can be followed by any one who is familiar with the common processes of analysis.

By the work done by a gear wheel, I mean the work done by the friction of sliding between the teeth. I shall leave out the small rolling friction between the teeth, and I shall not consider the friction of the shaft bearings.

The work lost by the rubbing of two surfaces on each other is the product of the normal force acting between the two surfaces,

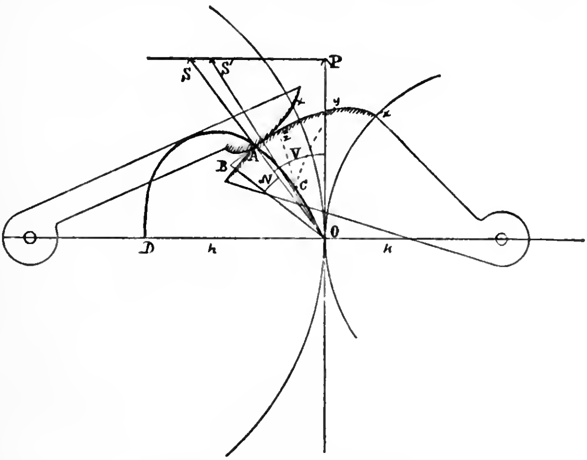


FIG. 1. Analytical Process.

by the distance through which the resistance is overcome, and by the coefficient of friction for the material in use.

To determine the work done by a pair of gear teeth, we must determine these three factors or their product, and this may be done in two different ways: by a graphical process, and by an analytical method. The two processes are entirely independent of each other beyond the given premises, and their agreement upon a common result is a substantial proof of the accuracy of both.

Graphical Process.—In *Fig. 1*, the two tooth curves have rubbed upon each other, while the point of contact between them has moved from C to A on the line of action, $O\,A\,D$, and they have done work that is the product of the coefficient of friction, f, by the difference, zy, of the lengths of the curves that have passed the

point of contact, and, for graphical purposes, of the average force, S', that has acted between the two teeth.

If we make a drawing, showing the two teeth in several positions, preferably at equal intervals of their action, we can determine the work done within the limits of each interval by multiplying together the factors as found by measurement. The total work done between any two points is the sum of these products for all the intervals between the points.

In *Fig. 2*, this process is applied to an exaggerated example of a pair of cycloidal teeth. The gears, with radii k and h, have ten

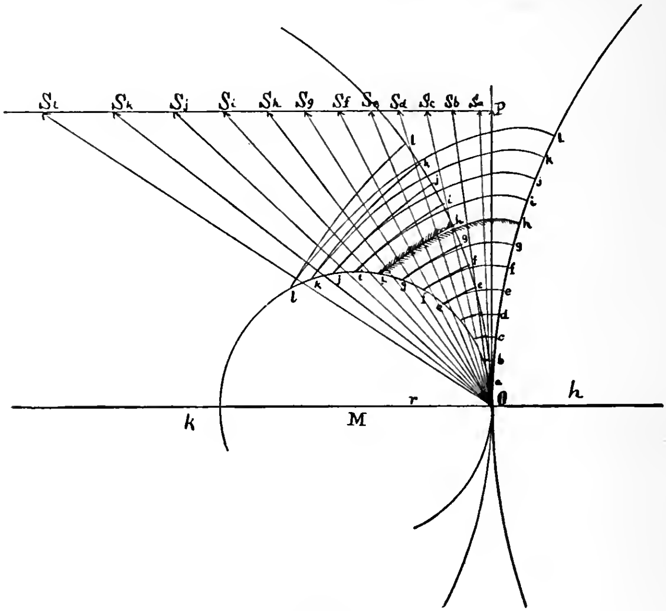


FIG. 2. Graphical Process.

and twenty teeth, the tangential force, $O P$, between the two gears is assumed to be constant and unity, and the coefficient of friction is assumed to be one-tenth. The describing circle, with radius $O M = r$, has three teeth, so that a gear of six teeth would have radial flanks and be the base or smallest gear of the interchangeable set to which the two gears belong.

The pitch and describing circles are divided into equal intervals, Oa, ab, bc, etc., of one-twelfth of the whole tooth arc, or circular pitch, Ol, commencing at the line of centres, and the work done over each of these small intervals is to be determined.

Make a templet of an epicycloid on the gear h, and of a hypocycloid within the gear k, and draw curves from each of the divisions of the pitch lines. Each pair of curves should meet on the corresponding division of the describing circle. Measure the differences between the lengths of these curves (see column 2 of the table), and by subtracting each total difference from the next larger, find the partial length of curve passed over during each interval, as tabulated at column 3.

Draw a line at an arbitrary distance, representing unity, from the line of centres and parallel with it, and draw lines, OSa, OSb, OSc, etc., through the centres of the intervals. The length of each line (column 4) can, with small error, be assumed to be the average normal force for its interval. These normal forces can be very easily computed, for each one is the reciprocal of the cosine of the angle POS. The angle for the first normal is $2\frac{1}{2}°$, and there are $5°$ between each of the following normals:

Multiplying together the normal for each interval, the partial curve for that interval, and the coefficient of friction, we obtain the loss for each interval as tabulated at column 5. By summation we obtain the total loss to and including each interval, as tabulated at column 6.

For the involute tooth, we have a constant normal force, $S = 1{\cdot}15$, the total work done, column 10, up to any interval is the product of that force by the total curve, column 9, for that interval. The figure is so similar to *Fig. 2*, that it need not be given here.

The graphical process will determine the general result, and show that while the two curves are substantially equal in efficiency, the advantage is a very little in favor of the involute. If we wish a precise comparison between these two curves, no graphical process can be used, and we must resort to analysis.

Analytical Process.—In *Fig. 1*, the two tooth curves are odontoids of any possible form, and they will secure a uniform velocity ratio between the pitch lines. They slide on each other, the point of contact moving along the line of action, $O\,A\,D$. At any time they are at a distance $O\,A = b$ from the pitch point, O, and are pressed together with a normal force, S, which is equal to the constant tangential force, P, divided by the cosine of the angle of obliquity,

$P\,O\,A = V$, and this normal force is always in the direction of the pitch point O.

While the normal, $O\,A$, turns through an elementary angle, the arc of which is $d\ V$, the two curves will rub on each other over an elementary distance, $A\,B = O\,A \cdot d\ V = b \cdot d\ V$, and they will do the elementary work

$$d\,W = f\,P \cdot \overline{A\,B} \cdot S \cdot = f\,\frac{P}{\cos\ V} \cdot b \cdot d\ V.$$

At the same time the wheel h will turn through the elementary angle, the arc of which is

$$d\,x = \frac{k}{k \pm h}\,d\ V$$

in which the positive sign is for external, and the negative sign is for internal contact.

Therefore, we have the total work done by friction, while the wheel h is turning through an angle, the arc of which is x.

$$W = f\,P\,.\,\frac{k \pm h}{k}\int_0^x \frac{b\,d\,x}{\cos\ V}$$

and this cannot be carried further until we know the form of tooth curve to be used, and can determine b and $\cos\ V$ in terms of x.

First take the involute tooth.

The distance $O\,A = b$ is equal to $h\,x\,.\,\cos\ V$, and we have the total work done

$$I = f\,P\,.\,\frac{k \pm h}{k}\,h\int_0^x x\,d\,x,$$

which integrates to

$$I = \frac{f\,P}{2}\,.\,\frac{k \pm h}{k}\,h\,\frac{x^2}{2},$$

or, if we use the arc on the pitch line, $w = h\,x$, we have

$$I = \frac{f\,P}{2}\,.\,\frac{k \pm h}{k\,h}\,w^2$$

for the value of the work done by the friction of involute teeth while moving from the pitch point over any arc, w, on the pitch circle.

It is a singular fact that this loss of power is the same for all

values of the angle of obliquity. All involute systems are equal in efficiency, without regard to the angle of obliquity.

Then take the cycloidal tooth.

We have $b = 2\,r\,.\,sin\,\frac{h}{2\,r}\,x$, and $cos\,V = cos\,\frac{h}{2\,r}\,x$, giving the total work.

$$E = f\,P\,.\,\frac{k \pm h}{k\,h}\,2\,r\int_{0}^{x} tan\,\frac{h\,x}{2\,r}\,d\,x,$$

which integrates to

$$E = -f\,P\,.\,\frac{k \pm h}{k\,h} 4\,r^2\ nat\ log\ cos\ \frac{w}{2\,r},$$

the value of the total work of a pair of cycloidal teeth.

To compare the cycloidal with the involute tooth for the same arc of action from the pitch point, divide E by I.

$$\frac{E}{I} = \frac{8\,r^2\ nat\ log\ cos\ \frac{w}{2\,r}}{w^2}.$$

As this is unity for $w = O$ and greater than unity for any finite value of w, it follows that the efficiency of the involute is mathematically superior to that of the cycloidal curve, in all cases and under all circumstances, without regard either to the angle of obliquity of the involute, the size of the describing circle of the cycloidal curve, or the arc of action, and provided only that the comparison is made over the same arc of action. (See column 13 of the table.)

In both of these formulæ it is seen that h and k can exchange places without affecting the result for external contact, and therefore the work done is the same, for the same arc of action, on both sides of the line of centres, the tangential force being constant.

For a comparison between external and internal gears, we have

$$\frac{A}{B} = \frac{I\ or\ E\ Ext.}{I\ or\ E\ Int.} = \frac{k + h}{k - h}$$

so that the internal gear is much the most economical, particularly when the two gears are nearly of the same size.

When $k = 2h$ we have $\frac{A}{B} = 3$. That is, if the internal gear is twice the size of its pinion, the work lost is but one-third of that lost when both gears are external.

Small improvement can be made by putting a small pinion inside, rather than outside of a large gear, as is often done at great expense on boring mills and large face plate lathes. A six-inch pinion and a six-foot gear will give $\frac{A}{B} = 1{\cdot}18$ an advantage of no great value.

It is seen from the above that the work being done increases very rapidly with the arc of action; with the square of that arc in the case of the involute, and in a still greater proportion for cycloidal teeth, and hence that arc should always be made as small as possible.

Strength should be secured by a wide face rather than by a large tooth, for the face of the gear has no influence on its efficiency.

The two formulæ for E and I can be very easily applied to any particular example, and the results obtained much more quickly, as well as more accurately than by the graphical method.

For application to the given example, where $h = 10$, $k = 5$, $f = l$, and $P = 1$, we have

$$E = 6{\cdot}2170\ [C - \log\cos (5\,n)^\circ]$$
$$I = {\cdot}01028\ n^2$$

in which n is the number of any interval, C, is the characteristic with the sign changed, and *log cos* contains only the mantissa of the common logarithmic cosine of $5\,n^\circ$.

It is seen from the tabulated value of E and I obtained by computation, columns 7 and 11, that the graphical and analytical processes agree very closely, the errors being shown by columns 8 and 12, as before stated, this agreement is a strong indication of the accuracy of both.

Prof. Reuleaux* finds that the two curves are exactly equal when compared over the same arc of action, and Prof. Hermann† finds the same result by a different process. In both cases the result was arrived at by making an approximation, for reasons not given but probably to simplify the work.

If the actual determination of the work done is the end in view, the approximations can be allowed, as the result is then close enough for all practical purposes. But, if the object is a close comparison between the two curves, the slightest difference must be accounted for, and neither Reuleaux's nor Herrmann's formulæ will answer the purpose.

Herrmann remarks, "It is evident, moreover, that the friction of involute teeth will be somewhat greater than that of cycloidal teeth, the angle γ being smaller for the former than for the latter."

This may be "evident," but it is not provable, and the statement that the angle γ, which is the complement of the angle of obliquity, is smaller for the involute, is not correct. Up to the half tooth point it is so, but beyond that point the reverse is true. At the half tooth point the two forms always have the same angle of obliquity if they belong to interchangeable sets which have the same base gear.

Further, it does not follow that the work of friction is the greater when the angle of obliquity is the greater, for the work of friction depends on two variable factors, the normal pressure, which indeed increases with that angle, and the length of the curve that is rubbed over. Within the half tooth point this curve is the shortest for the involute, so that the work done is the smallest although the other factor is the greatest.

As Herrmann states, "This difference is insignificant for the tooth profiles ordinarily employed," but the general impression, which it is the object of this paper to contradict, is that the difference is very significant and in favor of the cycloidal tooth.

Reuleaux goes further, and, after finding that the two curves are exactly the same for the same arc of action, gives several practical

* *Transactions of the American Society of Mechanical Engineers*, vol. viii, 1886. The result, without the demonstration, is also given in *Reuleaux's Konstrukteur*, § 213.

† Klein's translation of Herrmann's revision of *Weisbach's Mechanics of Engineering and Machinery*, vol. iii, § 79.

examples, which show the involute to be decidedly inferior, the difference being from sixty to eighty per cent.

This result is correct for the conditions of Reuleaux's examples, but it seems to me that those conditions are not correct if the object is to compare the two curves, for he does not take them on the same terms. He takes the involute with a long arc of action, and compares it with a cycloidal tooth having a short arc, and of course the involute is then inferior.

EXAMPLE FOR $h = 10\cdot$ $k = 5\cdot$ $r = 1{\cdot}5$ $f = {\cdot}1$ AND $P = 1$.

INTERVAL.	CYCLOIDAL TEETH.							INVOLUTE TEETH. OBLIQUITY, 30°. $S = 1{\cdot}15$.				$\frac{E}{I}$
					Total Work.				*Total Work.*			
	Total Curve	Partial Curve	Normal Force.	Partial Work	Graph	Anal's	Error	Total Curve	Graph	Anal's	Error.	
1	·010	·010	1·0009	·0010	·0011	·00103	·0001	·02	·0023	·00103	·0013	1·002
2	·035	·025	1·0087	·0025	·0036	·00413	·0005	·04	·0046	00411	·0005	1·004
3	·085	·050	1·0243	·0510	·0086	·00937	·0008	·08	·0092	·00924	0	1·013
4	·155	·070	1·0485	·0735	·0160	·01679	·0008	·15	·0173	·01645	·0008	1·021
5	·245	·090	1·0824	·0975	·0257	·02656	·0009	·22	0254	·02570	·0003	1·033
6	·355	·110	1·1274	·1240	·0382	·03884	0006	·32	·0370	·03701	0	1·049
7	·485	·130	1.1857	·1540	·0536	·05386	·0003	·44	·0508	·05038	·0004	1·069
8	·630	·145	1·2604	·1825	·0718	·07196	·0002	·57	·0658	·06580	0	1·094
9	·790	·160	1·3563	·2170	·0935	·09357	·0001	·72	·0831	·08328	0002	1·124
10	·965	·175	1·4802	·2590	·1194	·11932	·0001	·90	·1039	·10281	·0011	1·161
11	1·150	·185	1·6426	·3040	·1498	·15008	·0003	1·09	·1259	·12440	·0015	1·206
12	1·350	·195	1·8615	·3630	·1861	·18715	·0011	1·30	·1501	·14805	·0020	1·264
1	2	3	4	5	6	7	8	9	10	11	12	13

The work done increases rapidly with the distance of the point of contact from the line of centres, and the result of Reuleaux's method is to compare one curve that is at work a considerable distance from the line with another that is nearer to it.

This is clearly shown by the figures of Reuleaux's comparative examples, for in each case the losses are almost exactly proportional to the arcs of action.

For the purpose of comparison, the two teeth should be taken under precisely the same circumstances, and they should commence work and stop work together. They should have the same arc of action rather than the same addendum, for the addendum has very

little to do with the gear except by its effect on the maximum arc of action.

When taken under similar circumstances, involute and cycloidal gear teeth are practically equal with regard to the work done by friction, the difference being always slightly in favor of the involute.

Boston, Mass., February 21, 1887.

TURBINES.

By Irving P. Church, C. E.,

Assistant Professor Civil Engineering, Cornell University.

(*Concluded from Vol. cxxiii, page 331.*)

(1.) A *uniform* motion (constant velocity $= \omega r$) in the arc of a circle from O to O'.

(2.) An *accelerated* motion along the small arc $O B$ of the pipe; the acceleration of this motion being $= \frac{d c}{d t}$, its initial velocity $= c$, its final velocity $= c + d c$.

If the small arc $O B$ of the pipe remained parallel to itself, while O was passing to O', the particle would be at E', the further corner of the parallelogram formed on $O O'$ and $O B$, at the end of $d t$, and the two component motions just mentioned would be the only ones, the resultant motion being then $O E'$; but on account of the rotation of the pipe about c, the particle is really at B', at the end of $d t$, requiring us to compound with $O E'$ a third motion, $E' B'$ or $O E$, which may be regarded as rectilinear (being a small arc with centre at O'), and is, of course, accelerated, having an initial velocity of zero at O, and a final velocity of $p d t$ (p denotes the unknown acceleration of this motion and is regarded as constant during $d t$), and hence,

(3.) A uniformly accelerated rectilinear motion from O to E, normal to pipe curve at O, with initial velocity of zero (and whose acceleration p is thus found: Since $O E = E' B' = O B' \omega d t = c d t \omega d t = \omega c d t^2$, and since the distance described in a uniformly accelerated motion with initial velocity $=$ zero is equal to acceleration $\times \frac{1}{2}$ (time)^2, we have $\omega c d t^2 = \frac{1}{2} p d t^2 \therefore p = 2 \omega c$).

The only (horizontal) force acting on the particle at this instant is the pressure (call it N) of the side of the pipe and acts along $C'' O$, but is not shown in the figure; in magnitude and direction, however, it must be equivalent (*i. e.*, must be the resultant) of any imaginary system of forces capable of producing the three component motions just mentioned. To determine an imaginary equivalent system, we have only to apply to the three component motions the following well-known theorems for the dynamics of a "material point," or small particle (based directly upon Newton's laws):

Theorem A.—If the particle is moving in a right line with an accelerating velocity, the resultant force must act along that line, in the same direction as the acceleration, and have a magnitude = mass of particle × acceleration.

Theor. B.—If the particle is moving with uniform velocity in a curved path, the resultant force at any instant must be directed toward the centre of curvature and have a magnitude = mass of particle × square of velocity ÷ the radius of curvature.

Theor. C.—If the particle is moving with accelerating velocity in a curved path, the resultant force at any instant is equivalent to two forces, viz., a tangential force = mass × acceleration of the velocity (in same direction as the acceleration), and a normal force (*toward* centre of curvature) = mass × square of velocity ÷ radius of curvature.

Our imaginary system of forces, then, equivalent to the force N, or pressure of the side of pipe against the particle, is constructed as follows:

The component motion, No. 1, can be produced by a force along $O\ C = P_1 = M(\omega r)^2 \div r = \omega^2 M r$ (in which M denotes the mass of the particle), by Theorem B, see *Fig. 6* for positions of forces.

Motion No. 2, by Theorem C, can be produced by the two forces P_2, normal to pipe, $= M c^2 \div \rho$, and the tangential force $P_2' = M \times \text{acc.} = M(d\,c \div d\,t)$; while motion No. 3, by Theorem A, can be produced by a force $P_3 = M \times \text{acc.}$, *i. e.*, $P_3 = 2\,M\,\omega\,c$ (see above) along $O\ E$, *Fig. 6.*

Denote the angle $C''\ O\ C$, between the two radii of curvature, by μ (Mr. Woodbridge's γ); then, since the real force acting, N, acts in the line $C''\ O\ E$ normal to side of pipe, and is equivalent to the imaginary four forces, P_1, P_2, P_2' and P_3, of *Fig. 6*, it must

be equal to the algebraic sum of their components along $C'' \, O \, E$, *i. e.*,

$$N = M \left[\frac{c^2}{\rho} + \omega^2 r \cos \mu - 2 \omega c \right] \qquad (g)$$

which is the value of the pressure of the pipe against the particle at this instant. In *Fig. 6*, N is supposed to have the same direction as P_2', but if a negative result is obtained from equation (g) in any particular case, N must have the direction of P_3.

[With *Fig. 6*, as drawn here, a negative N from equation (g) indicates that the pipe is doing work upon (*i. e.*, transmitting energy to) the particle, *i. e.*, is accelerating the absolute velocity of the particle; while a positive value shows the converse, that the particle is doing work upon the pipe and its connections (this energy, however, is spent in work external to pipe, not in accelerating the rotary motion of the pipe, for ω by hypothesis is constant throughout this discussion). This is similar to the distinction between the modes of working of a centrifugal pump and a turbine. The former does work upon the water which is pumped, with a large value for the wheel-rim velocity; while the latter, with its connected machinery, is driven *by* the water, with a wheel-rim velocity regulated to a moderate value for best effect.]

Again, the real force N has no component tangent to the side of pipe $O \, B$, and hence the algebraic sum of the components of the imaginary forces perpendicular to $C'' \, O \, E$ must be zero; *i. e.*,

$$M \frac{d\,c}{d\,t} - \omega^2 M r \sin \mu = o$$

But, see *Fig. 6*, $\sin \mu = B \, K \div O \, B = d \, r \div c \, d \, t$, whence, by substitution,

$$M \left[\frac{d\,c}{d\,t} - \frac{\omega^2 r \, d \, r}{c \, d \, t} \right] = o. \qquad (h)$$

Reducing (h), we obtain

$$c \, d \, c = \omega^2 r \, d \, r;$$

which contains but two variables, c and r, already separated. Integrating between some initial point 1 of the pipe, and any other, we have

$$\int_{c_1}^{c} c \, d \, c = \omega^2 \int_{r_1}^{r} r \, d \, r \, ; \text{ or, } c^2 - c_1^{\,2} = \omega^2 (r^2 - r_1^{\,2}) \qquad (k)$$

showing that c is a function simply of the distance from the axis, being independent of the form of the pipe.

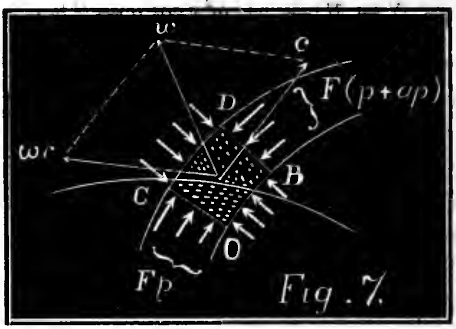


Fig. 7.

We may now utilize the imaginary system of forces in *Fig. 6*, in considering the absolute motion, in time dt, of the small prism, or lamina, of water in *Fig. 7*, included between two cross-sections of a turbine-channel, a distance $OB = c\,dt$ apart. Let p denote the mean pressure per unit-area on the face CO, then $p + dp$ is the pressure on DB. Let F denote the area of each of these faces. The real forces acting (horizontal), are the Fp and $F(p + dp)$ just mentioned, and the pressures from the partitions; these latter having no components tangent to OB. The sum of the components along OB of the real forces must equal the corresponding sum for an imaginary equivalent system like that shown in *Fig. 6*. The latter sum we have (in form) in the left hand member of equation (h), hence

$$d\,M\left[\frac{d\,c}{d\,t} - \frac{\omega^2 r\,d\,r}{c\,d\,t}\right] = -F\,d\,p$$

But now the mass, dM, is the mass of the small lamina, and $= F\,\overline{OB}\,\gamma \div g$, *i. e.*, $= F(c\,dt)\gamma \div g$, whence, after substitution and reducing, etc.,

$$\frac{1}{g}\,c\,d\,c = \frac{\omega^2}{g}\,r\,d\,r - \frac{1}{\gamma}\,d\,p \tag{k}$$

in which the three variables, c the relative velocity, r the radius vector, and p the internal liquid pressure, are separated.

Now the flow being "steady," and considering the whole stream from entrance (position 1) to exit (position n) of the channel to be subdivided into equal small laminæ, then, in any one dt these

laminæ simultaneously advance, each into the position (in the pipe, or channel, not in space), which the lamina just ahead occupied at the beginning of the dt, and each lamina thus assumes the same values of c, r, and p, which its predecessor had, dt before. Hence, if we write out an equation like (k) for each lamina between 1 and n, and sum corresponding terms, we obtain

$$\frac{c_n^2}{2g} - \frac{c_1^2}{2g} = \frac{(\omega r_n)^2 - (\omega r_1)^2}{2g} - \frac{p_n}{\gamma} + \frac{p_1}{\gamma} \qquad (1)$$

which is equation (6) of Mr. Woodbridge's article, and may be called Bernoulli's theorem for steady flow through a uniformly rotating horizontal pipe.

Thinking it will not be out of place in this connection, the writer wishes to offer some criticisms on parts of articles in this journal by Prof. Wood and Mr. Frizell, in which the problem of the friction-less particle in a horizontal tube rotating with uniform angular velocity about a vertical axis is considered. On p. 419, JOURNAL FRANKLIN INSTITUTE, June, 1884, Prof. Wood presents an amended version of Weisbach's treatment for finding the law of change of the relative velocity, in which he states that the acceleration of the relative velocity is just the same as if due solely to the component along the tube of a force $\omega^2 M r$, equal and opposite to the radial force which *would* be exerted on the particle by the tube, *if* the former, relatively at rest, were to accompany the tube in its rotation, *i. e.*, with the same angular velocity, ω, as the tube.

This is doubtless true, since the relation $c\,d\,c = \omega^2 \rho\, d\, \rho$, which it implies, can be proved by straight-forward fundamental methods; but is it not too much to ask of a student, to grant such a postulate? It may seem reasonable to him, perhaps plausible, but the fact that the angular velocity of the particle after release from the imaginary constraint is not ω, may arouse doubts in his mind, as it did in that of Mr. Frizell (JOURNAL FRANKLIN INSTITUTE, August, 1883, p. 92); while again, from Prof. Wood's statement, "the component normal to the tube will simply produce a pressure against the side of the tube," he will infer that that pressure must therefore $= \omega^2 M \rho \cos \theta$. But this latter relation is not true, as the student would doubtless conclude after a little thought, since the tube may have such a form that the particle exerts no pressure (horizontally) against it, and at points where $\cos \theta$ is not zero.

The instructor might then reply, perhaps: "Yes; but the pressure against the tube depends on other agencies as well;" and the student could rejoin: "But how am I to know that these 'other agencies' have no influence on the relative velocity?"

On the whole, then, may we not conclude that even this amended form of Weisbach's demonstration is altogether too artificial and unsatisfactory (although so brief in its algebra) for presentation to a beginner in mechanics? If any fictitious forces are to be called into play, is it not better to employ such a complete system, like that in *Fig. 6*, of this article, as may be easily proved to be the full equivalent, in *all* respects, of the real force acting, viz., the unknown wall-pressure?

In the JOURNAL FRANKLIN INSTITUTE, for July, 1884 (p. 29), appeared one article by Mr. Frizell on the discharge of turbines, to which the present writer would have replied long ere this, if by some mischance he had not missed seeing that number at the time, and thought afterward that he had examined all the numbers of that year. Two months ago in a bound volume in the University Library it casually came to his notice.

Weisbach's fictitious "centrifugal force" $P = \omega^2 M r$ (see p. 93, JOURNAL FRANKLIN INSTITUTE, August, 1883), Mr. Frizell proposes to replace by the following,

$$P = M\left[(\omega - \omega_1)^2 r - v\right] \qquad \text{(m)}$$

(p. 31, JOURNAL FRANKLIN INSTITUTE, July, 1884), in which ω and ω_1 are the respective angular velocities of the wheel, and of the particle with respect to the wheel, r the radial distance of the particle from wheel axis at any instant, v the radial component of the absolute velocity of the particle, and M the mass of the latter. Of these quantities, ω_1, r, and v are variable, M and ω constant. (In the August number, 1883, Mr. Frizell upheld Weisbach in the statement that $P = \omega^2 M r$ for a radial tube, whereas equation (m) would reduce to $P = \omega^2 M r - M v$ in such a case.)

The most prominent feature of this formula (and one which Mr. Frizell must have noticed ere this), that it is not homogeneous, *i. e.*, that in the bracket we have combined, by algebraic addition, two quantities of *unlike kinds*, for $(\omega - \omega_1)^2 r$, is an *acceleration*, while v is a *velocity*. This incongruity alone shows it to have no sound basis in theory, but as Mr. Frizell seems to place more

reliance on particular cases than in general demonstrations, let us apply one or two tests to equation (m) as applicable to the problem of the particle in the rotating tube, or top.

First, algebraically, suppose the tube straight and radial, and at rest; *i. e.*, $\omega = o$, $\omega_1 = o$; while v becomes the absolute velocity, which we may call w. Equation (m), then, would assert that the particle is under the action of a force, acting inward along the tube, of a value

$$P' = -Mw.$$

But if any such force exists (and the incongruity above mentioned is now quite apparent; Mw is momentum, not force), the motion along the tube must be retarded; but we know practically that in a straight horizontal tube at rest there is no force to change the velocity of the particle (friction aside).

Secondly, a numerical test. As is well known, any formula in pure mechanics, properly based on sound principles, while as yet in symbolic form (*i. e.*, containing no numerals but abstract numbers, like the 2 in $c = \sqrt{2\,g\,h}$ for a falling body) will give identical results whatever system of units be employed; (the equation may then be called *homogeneous*). Now equation (m), if true, should endure such a test; for as yet no numerical substitution has been made which commits us to any special system of units (Mr. Frizell's announcement about the foot and second a few lines before is premature; he surely would not claim that $c = \sqrt{2\,g\,h}$, for example, is true for the foot and second, and not for the metre and minute).

Let us take $(\omega - \omega_1) = 4$ radians per second (the radian being the unit of π-measure, or circular measure, being the angular space of which it takes 6·28 .... ($2\,\pi$) to make a full revolution; the term, feet per second for angular velocity, used by Mr. Frizell, is entirely out of place since angular space is independent of units of length); $v = 12$ feet per second; $r = 1$ foot; and the weight of the mass $= 0·644$ pounds.

Adopting the foot-pound-second system of units, in which $g = 32·2$, and hence substituting the above numerals in equation (m), we obtain

$$P = \frac{0·644}{32·2}\left[4^2 \times 1 - 12\right] = 0·08 \text{ pounds.}$$

Now changing to the foot-pound-*minute* system, in which $g = 32·2 \times 60^2 = 115920·$ we substitute $(\omega - \omega_1) = 4 \times 60 = 240$ radians

per minute, $v = 12 \times 60 = 720$ feet per minute, r and the weight as before, and obtain

$$P = \frac{0{\cdot}644}{115920}\left[240^2 \times 1 - 720\right] = 0{\cdot}316 \text{ pounds,}$$

which is by no means identical with the 0·08 pounds previously found; the natural result of using a non-homogeneous equation.

In the turbine computations, taking experiment No. 21, the "common theory," without any considerations of friction, gives the volume discharged per second as

$$Q = 161{\cdot}87 \text{ cubic feet per second,}$$

(derived from equation (16), p. 340, JOURNAL FRANKLIN INSTITUTE, May, 1884), the experimental result being 139·9 cubic feet per second. Mr. Frizell's formula for Q is that of the common theory with the "centrifugal term" replaced by a quantity based on the erroneous relation in equation (m), and without friction gives $Q = 152{\cdot}6$ cubic feet per second. If now the unit of time be changed to the minute, equation (16) of the writer gives

$$Q = 9712{\cdot}20 \text{ cubic feet per minute,}$$

a result identical with that first mentioned; while Mr. Frizell's formula, on account of its non-homogeneous term, will yield a *new result every time the unit of time is changed.*

By considering friction (in doing which it is curious to note that Weisbach's coefficients are adopted, based as they must have been on a comparison between Weisbach's theory and experiments) Mr. Frizell's apparent result $Q = 152{\cdot}6$ cubic feet per second, which is only ten per cent. in excess of the 139·9, is diminished to about five per cent. excess, which is finally abrogated by utilizing the rather remarkable assumption that if the sectional area of a guide passage (running full) is F and the "*velocity through* F" is $= c$, then the discharge through F is not $Q = Fc$, but *five per cent. less.*

Mr. Frizell's computations, then, simply amount to this: That, restricting its use to a definite unit of time, the common theory may be so modified by replacing the "centrifugal term" by an empirical expression, that by using Weisbach's mean coefficients for skin-friction head, and considering the loss of head due to impact at entrance, the computed discharge for the Tremont turbine will be about five per cent. greater than that observed in Mr. Francis' experiments.

Returning to the problem of the tube and the particle, another test which any one can easily apply for himself, to prove that the equation

$$c_2^2 - c_1^2 = v_2^2 - v_1^2 = (\omega r_2)^2 - (\omega r_1)^2$$

(p. 612, *Coxe's Weisbach*) is correct in the particular case when the path is a *straight line in space*, the particle not touching either side of tube, is this: Referring to *Fig. 2*, of this article, suppose $M N$ to be the straight absolute path, then the particle not touching either side of the tube will preserve its absolute velocity, w, unaltered, *i. e.*, w, at $M = w_2$ at $N = w$. Knowing the wheel velocity at M, $v_1 = \omega r_1$, and at N, $v_2 = \omega r_2$, construct parallelograms at M and N to determine the relative velocities, c_1, and c_2, as on p. 612, *Weisbach*. If this be done graphically, and the values of c_1 and c_2 scaled off, the relation $c_2^2 - c_1^2 = v_2^2 - v_1^2$ is easily verified by substitution. Or, by formulæ (and without numercial verification) if a_1 is the angle between w and v_1 at M, a_2 between w and v_2 at N, we have by trigonometry,

$$c_1^2 = w^2 + v_1^2 - 2\,w\,v_1\,cos\,a_1$$

$$c_2^2 = w^2 + v_2^2 - 2\,w\,v_2\,cos\,a_2$$

whence, by subtraction,

$$c_2^2 - c_1^2 = v_2^2 - v_1^2 - 2\,w\,(v_2\,cos\,a - v_1\,cos\,a_1)$$

But the length of the perpendicular from the wheel axis upon the right line, $M N$, is

$$r_1\,cos\,a_1 = r_2\,cos\,a_1$$

$$\therefore\ \omega\,r_1\,cos\,a_1 = \omega\,r_2\,cos\,a_2,\ \text{or},\ v_1\,cos\,a_1 = v_2\,cos\,a_2$$

whence, finally,

$$c_2^2 - c_1^2 = v_2^2 - v_1^2 \qquad Q\ E\ D.$$

It is, perhaps, hardly necessary to say that, although some of the writer's deductions have been stated in a very positive manner in this article, no discourtesy is intended; he is simply sure he is right, and "goes ahead." As to his discussion with Mr. Frizell, the burden of proof rests with the latter, since he (in August, 1883) first declared Weisbach's result in the purely theoretical problem of the top and the particle to be erroneous.

Ithaca, December 28, 1886.

ALUMINIUM AND ITS ALLOYS; WITH EXPERIMENTAL INVESTIGATIONS.

BY EDWARD D. SELF, Stevens Institute of Technology.*

(*Concluded from Vol. cxxiii, page 322.*)

In general, the ten per cent. bronze works much better and cleaner than brass, and takes a more beautiful polish which it retains longer. These properties make it eminently suited for philosophical and other instruments, as it not only takes a beautiful lustre, but under ordinary circumstances does not require to be shellaced.

The resistance of the bronzes to corrosion in sea and mine water does not seem to be well sustained. Water containing alkaline carbonates, however, did not noticeably attack the specimens tested. As it seemed best to prepare a solution that would contain the injurious elements usually found in mine waters, rather than employ a real mine water that might contain only some of the ingredients frequently found in such waters, the following solution was prepared:

$Na\,Cl$,	100 grams.
$Na_2\,CO_3$,	100 "
$Fe_2\,Cl_6$,	100 "
Alum,	100 "
$Ca\,Cl_2$,	100 "

These substances were dissolved and diluted to a litre and neutralized.

The salt water used was taken from the middle of the Hudson River, at high tide, as at that time the influence of the upper fresh waters was the least easily felt, and in reality appreciably nothing.

The alkaline solution was prepared by dissolving 500 grams of $Na\,CO_3$ in a litre of water. The pieces of metal used were strips of sheet metal containing about five square inches. They were all carefully buffed to remove the scale or oxide formed in rolling, and all traces of grease were removed.

When placed in the mine water solution the pieces of metal were quickly attacked and turned black, or gray with shining

* Graduation Thesis, 1886.

specks in a day or two. The bright specks appeared not only on the metal, but on the surface of the liquid also.

The following are the data:

Name.	*Mark.*	*First Weight.*	*Second Weight.*	*Loss.*
5 per cent.,	A_2	7·999 mgs.	7·329 mgs.	·670
7½ "	B_2	9·058 "	8·076 "	·982
10 "	C_2	9·9385 "	8·961 "	·9775

Time, 50 days.

In the cases of the first and second, above given, the pieces were bent to admit of placing them in a small beaker. On the final examination, it was found that the lower part of the bend, resting on the glass, showed a bright copper-colored surface, as though the pieces had been copper with a bronze plating, which was there destroyed. The pieces in this test were all thickly coated with carbonate of copper where they were exposed to the air. The surface of the liquid was also thickly covered with a green mass.

The specimens immersed in salt water gave the following results:

Name.	*Mark.*	*First Weight.*	*Second Weight.*	*Loss.*
5 per cent.	A_1	9·767	9·704	·063
7½ "	B_1	9·658	9·591	·067
10 "	C_1	10·227	10·154	·073

Time, 50 days.

The pieces were placed in a flat dish, and salt water added from time to time, to replace that lost by evaporation. The action was not very rapid, but a green scum was produced and finally settled on the pieces. The phenomena were similar to the mine-water test, but very much less marked. The solution of alkaline carbonate remained colorless, and the pieces were not visibly acted upon or changed.

TENSILE TESTS.

The ingot, already described, was again cut with a parting-tool to obtain a tension test piece of the maximum length possible; but even this was found to be too short to admit of proper securing, and the following expedient was adopted:

Wrought-iron bars about 4 inches long, with a diameter of 1¼ inches, and having an enlargement of about an inch in the diameter, extending about one-third the way from each end, were employed. A ⅞-inch hole was bored in one end of each piece and

a V-thread, with $\frac{1}{12}$ inch pitch cut in each, before removing from the lathe. The ends of the test piece were now cut with a diameter sufficient at the ends to admit of cutting a thread to fit the wrought-iron nuts already prepared. After screwing the bronze into the nuts and tightening only enough to insure that the threads were in contact throughout, the piece was placed in a Riehlé testing machine of a capacity of 40,000 pounds, and held in perforated chucks, and at the bottom of which was a ring or shoulder, to prevent the wrought-iron nuts from being drawn through. On each end of the test piece were screwed two micrometer screws, reading to $\frac{1}{10,000}$ inch, and abutting pieces, respectively. By employing the method of electrical contact, the extension was easily read to within two or three ten-thousandths of an inch. The axis of the specimen was very carefully made parallel to the direction of the pull to be applied, to eliminate all shearing stresses.

The following are the data derived from this test. Sets were taken occasionally.

Diameter of specimen, ·675 inches between fillets. Length between fine centre punch-marks at bottom of fillet, 7·66 inches.

Load Pounds.	*Micrometer I.*	*Micrometer II.*
150	1·1416	1·1735
2,000	difference, 55	
3,000	" 25	
4,000	1·1463	1·1804
Set 150	1·1407	1·1747
4,500	1·1455	1·1817
5,000	1·1460	1·1826
5,500	66	35
6,000	79	43
Set 150	1·1412	1·1756
6,250	1·1486	1·1849
6,500	93	54
6,750	1·1500	58
7,000	10	69
7,250	17	76
7,500	25	89
7,750	35	1·1908
8,000	46	20
Set 150	1·1478	1·1830
8,250	1·1565	1·1940
8,500	80	54

Load Pounds.	*Micrometer I.*	*Micrometer II.*
Set 150	1·1478	1·1830
8,750	1·1597	1·1981
9,000	1·1619	1·1986
9,250	36	1·2007
9,500	71	40
9,750	83	61
10,000	1·1720	96
Set 150	1·1549	1·1993
10,250	1·1785	1·2123
10,500	90	48
10,750	1·1823	73
11,000	58	1·2208
11,250	1·1908	40
Set 150	1·1681	1·2051
12,000	1·2035	1·2370
13,000	1·2255	1·2565
Set 150	1·2186	1·2540

At this point, the extension became so great as to indicate that nearly the maximum load had been applied. For this reason, the micrometer screws were removed, and the distances between the "centre-punch" marks measured occasionally, with fine pointed dividers and scale.

Load Pounds.	*Lengths.*	*Remarks.*
14,000	7·7 inches.	
16,000	7·8 "	
18,000	7·91 "	
19,750	. . . "	This load stripped the *wrought-iron* thread in nut, not injuring the bronze. The chucks of the machine were then brought closer together, and flat wedges with V-grooves substituted for the nut and collar.
20,160	. . . "	Ditto (other end).
20,160	8·1 "	Broke one of the steel-wedges horizontally; wedge about $4\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$ at smallest end.
23,160	. . . "	Specimen broke near fillet. The test took nearly five hours on account of the above unusual difficulties.

The piece, where broken, showed a much striated surface, and the fracture was fine and silky in appearance, and in this particular exhibited many characteristics of wrought-iron or low-grade steel.

The specimen, after fracture, showed many evidences of a high

ductility. An examination of the results of the test shows that the elastic limit, as in copper alloys generally, is ill defined. This is seen on reference to the curve of extensions given on the next page. The limit of elasticity is, however, at the point where the extensions suddenly increase for equal loads.

It has already been stated that the tenacity and good qualities of aluminium-bronze improve after several meltings.

This is shown by the results of some tests, subsequently made, of ten per cent. bronze, either melted but once or twice, or else when melted, badly chilled in casting. The specimens were already cast into approximate forms for testing and required only to be turned to size. They were unfortunately too short to admit of applying the micrometer screws for measuring the extension with accuracy.

Name.	*Mark.*	*Diameter.*	*First Length*	*Second Length.*
10 per cent. Al Br.	I	·796 inches.	2·43 inches.	2·495 inches.
10 " "	II	·617 "	2·64 "	2·74 "

The breaking loads and tenacities were :

Mark.	*Breaking Load.*	*Tenacity.*
I	27,300 pounds.	55,532
II	14,654 "	48,979

Both of these pieces showed very poor fractures, and seemed to contain free impurities; there were also apparent long crystals, arranged radially about the axis of the pieces. These defects were evidently produced at the same time. From this mishap in their preparation, the tenacities above given are no real criterion by which to judge the properties of the bronze. Several tensile tests were made with thin sheet metal, that showed in one instance a remarkable strength.

These tests were made on an Olsen machine, which, for the small loads required, is more accurate than the large machine already mentioned. The specimens were cut nearly to size, and shaped afterwards, by filing. Fillets were also cut with the file, and the central part of the piece made narrower to avoid a possible break in the chuck.

Mark.	*Length.*	*Breadth.*	*Thickness.*	*Tenacity.*
5 per cent. Al Br.	3·764 inches.	1·472 inches.	·015 inches.	40,846
7½ " "	3·655 "	1·495 "	·015 "	102,567
10 " "	3·795 "	1·483 "	·015 "	51,680

The extension in each case above was about

5 per cent. bronze, ...	11·2 per cent.
7½ " "	3·0 "
10 " "	4·1 "

These results are a fair average of others that were obtained after the thesis work proper had been completed. The appearance and tenacity of the seven and one-half per cent. specimen indicate that an error was probably made in the original marking, as the tenacity seems without doubt to belong to the ten per cent. bronze. The marks, however, are the same as those furnished the writer.

COMPRESSION TESTS.

These tests were made with specimens cut from original ingot on the planer. The pieces were made of such a size as to first give or yield by buckling, as it is evident that a piece over a few diameters long would thus yield in practice. The tests were made with the compression appliances for the Riehlé machine. An attempt was made to obtain the elastic limit of compression, by use of the micrometer screws, but as the pieces crushed unevenly in each instance, this effort was necessarily futile. The micrometer screws were then removed, and the buckling and actual breaking load observed.

Name.	*Diameter.*	*Buckled at—*	*Broke at—*
10 per cent., Al Br.	·514 inches.	14,500 pounds.	25,000 pounds.
10 " "	·510 "	9,600 "	18,100 "

which gives a resistance to compression of about 125,000 and 88,700 pounds.

The difference in breaking loads is due to the fact that the length of the first was 1·845 inches and the second was 2·0 inches. The final break in each case occurred at the end of the piece, and was such that the final length could not be ascertained. The pieces showed evidence of a considerable "flow" having taken place. This was equally noticeable in the tension and torsion tests.

TORSION TESTS.

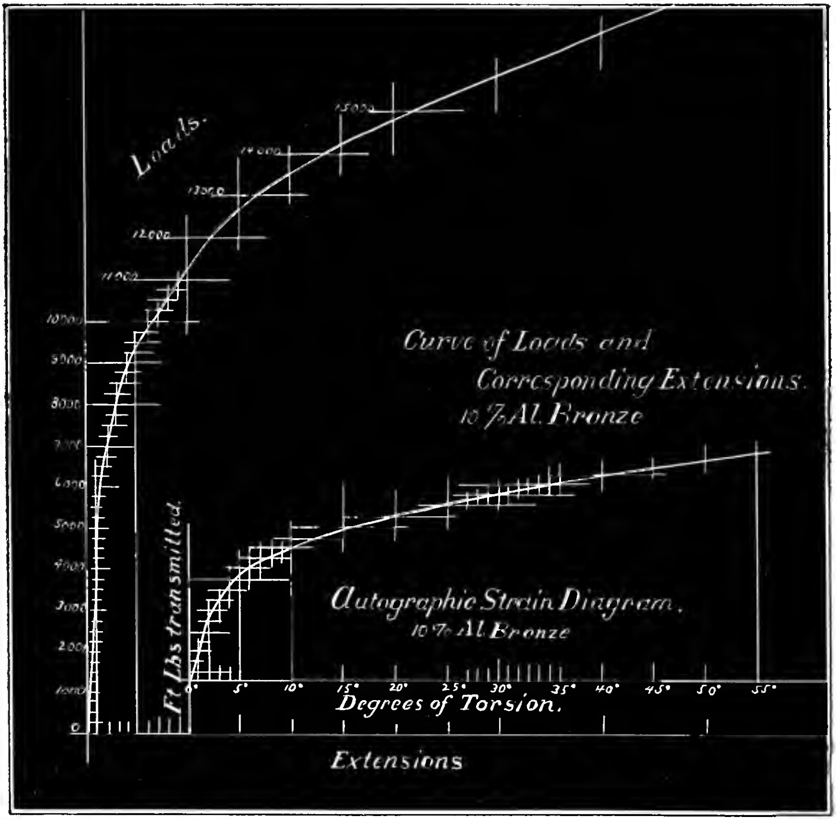
These were made on Thurston's autographic testing machine. The specimens were carefully turned to ⅝ inch diameter and 1 inch long between shoulders. Three pieces were tested, and the results agreed very closely. The following is a mean:

Diameter.	*Degree of Torsion.*	*Elastic Lim.*	*Moment Transmitted.*
·626 inch.	56°·1	4°·1	22·0 foot pounds.

The moment transmitted up to the elastic limit was 9·2 foot

pounds, and the total extension of an exterior fibre was about ·0456.

The strain diagram produced runs up a little higher than that of some wrought irons, but ultimately breaks at less than one-quarter the torsion. The elastic limits of the two metals very



NOTE.—The Curve beyond 13,000 is approximate only. Breaking Load, 23,160 pounds. Tenacity, 65,184 pounds.

nearly agree, and as this is properly the most important consideration, we may say that for resisting torsion, the ten per cent. bronze is substantially as good as wrought iron.

From an inspection of the autographic curve, most of the properties can be discovered that tend to establish the usefulness of the bronze.

ELECTRICAL CONDUCTIVITY.

The electrical resistance of two pieces of Al bronze wire was obtained by the usual methods. The wire was wound in coils and insulated by paper. The heat obtained was from an air-bath. The following are the actual resistances obtained at different temperatures, Centigrade, by three experiments with the same wire. It will be observed that the resistance was variable as the temperature increased, and is doubtless caused by molecular changes until the wire became annealed.

Temp. C.°	*Resist. Ohms.*	*Temp. C.°*	*Resist. Ohms.*	*Temp. C.°*	*Resist.*
32·	1·81	18·	1·79	19·	1·79
34·	1·84	31·	1·80	28·	1·80
47·	1·85	40·	1·80	53·	1·81
53·	1·86	43·5	1·81	63·	1·815
58·	1·87	52·	1·82	67·	1·82
63·	1·88	63·	1·82	78·	1·83
69·5	1·89	72·5	1·83	89·	1·835
76·	1·89	85·	1·84	91·	1·835
79·	1·89	92·	1·845	92·	1·835
80·	1·89	94·5	1·845	93·	1·84
90·	1·89	95·	1·85	95·	1·84
95·5	1·89	96·	1·85	96·	1·85
97·5	1·89	97·7	1·86	96·5	1·855

Weight of above five per cent. wire, ... 3·219 grams.
" " " " " per foot, . . . ·4315 "

The length of wire used was 7·46 feet, which gave a resistance of about ·24 ohms per foot at 65° F.

The piece of ten per cent. wire being short and of large diameter, it was deemed advisable to secure to its ends large pieces of copper wire to be passed to the binding posts, where it was connected. Many attempts were made to unite the copper and bronze wires by solder, but in no case could a firm joint be made. The ends of the copper wires were finally drilled, and the bronze wire was inserted and held by hammering the ends of the copper wires to close the holes tightly on the bronze.

The following table of resistances was obtained on treating the wire similarly to the five per cent.

Temp. C.°	*Resist. Ohms.*	*Temp. C.°*	*Resist. Ohms.*	*Temp. C.°*	*Resist.*
20	·13	22	·13	18·25	·14
25	·13	24	·13	25·	·14
32	·13	43	·14	32·	·14
36	·13	63	·14	50·	·145

Temp. C.°	*Resist. Ohms.*	*Temp. C.°*	*Resist. Ohms.*	*Temp. C.°*	*Resist.*
43	·13	73	·145	59·	·15
53	·13	84	·15	63·	·15
60	·13	88	·15	72·	·15
70	·14	90	·15	79·	·15
77	·14	94	·15	82·	·15
81	·14	95	·15	84·	·15
85	·15	..	..	86·	·15
90	·15	..	..	90·	·15
93	·15	..	..	93·	·15
95	·15	..	..	95·	·15

The length of this wire was 4·36 feet and weighed 7·9582 grams per foot, giving a resistance at ordinary temperatures of about ·03 ohms per foot.

The heat-conductivity of five and ten per cent. bronzes is very high, and not much less than that of copper. The experiments which showed these results were made with pieces of bronze, which, though unsuitable, were the best obtainable at the time. As the work was therefore made under unfortunate conditions, the results obtained probably only express the relations each alloy sustains to copper in conductivity.

The writer is preparing to take up the subject of conductivity of heat with more suitable material and apparatus, and somewhat enlarge the field of investigation. The details of the experiments and methods pursued, can be better explained then than now.

The conductivity of the five per cent. was nearly equal to the copper used, while that of the ten per cent. was slightly less.

FRICTIONAL TESTS.

The frictional or anti-frictional properties of aluminium-bronzes have so long been boasted in various writings, that the results of the following tests, made on Thurston's lubricant tester, may be of interest.

A sleeve of ten per cent. bronze was turned to run accurately in hardened steel boxes, placed in the pendulum of the above machine, and run at 300 pounds pressure and 1,200 revolutions per minute, until the surfaces in contact were worn smooth. During this process, the pendulum was occasionally removed to admit of polishing with crocus cloth, the places that had worn rough. After the journal had thus been run for a day, a similar one of ordinary box metal was treated in the same way. After each was made perfectly smooth, they were carefully cleaned from oil with benzine, cooled and weighed.

The test then made consisted in running each for ninety minutes, and noting the temperature of the journal and deflection of the pendulum every five minutes.

The steel boxes used were cut away on the sides and came in contact with the journal only on the top and bottom. This permitted a greater pressure to be employed and allowed a freer circulation of oil. The oil used was winter bleached sperm, used as a standard for comparing oils sent to the STEVENS INSTITUTE to be tested.

An observation of the following table will show the exact behavior of each alloy tested.

AL BRONZE, 10 PER CENT.			BOX METAL.		
Temp. F.°	*Deflec.*	*Time.*	*Temp. F.°*	*Deflec.*	*Time.*
84	1·5	0	75	1·6	0
90	1·4	5	83	1·6	5
94	1·4	10	90	1·5	10
99	1·3	15	95	1·4	15
102	1·3	20	99	1·4	20
108	1·3	25	102	1·3	25
110	1·3	30	104	1·3	30
110	1·3	35	104	1·3	35
110	1·2	40	105	1·3	40
110	1·2	45	105	1·3	45
111	1·2	50	105	1·2	50
111	1·1	55	107	1·2	55
111	1·1	60	109	1·2	60
111	1·1	65	109	1·2	65
111	1·1	70	109	1·2	70
111	1·1	75	109	1·2	75
111	1·1	80	109	1·2	80
111	1·1	85	109	1·2	85
111	1·1	90	109	1·2	90

Weight of bronze before test, ...	148·918 mgs.	Weight of box metal before test, ...	166·3675 mgs.
Weight after, ...	148·890 "	Weight after, ...	166·3635 "
Difference, ...	·028 "	Difference, ...	·004 "

From these data, it is noticed that with the bronze journal, the friction is less and the temperature of the journal higher; but the wear is very great compared with box metal.

The loss of weight is probably greater than if a steel journal were used to run in aluminium-bronze boxes.

The wearing capacity of the bronze doubtless depends on a

very slight change of some of its ingredients, or the addition of some hardening element. If the excessive wear can be prevented without, at the same time, increasing the friction or temperature of running, aluminium-bronze can be made a formidable competitor with the various box metals in the market.

The following analysis of ten per cent. bronze was made in the chemical laboratory of STEVENS INSTITUTE.

Carbon,	1·5 per cent.	1·3 per cent.
Silicon,	6·4 "	6·5 "
Copper,	87·5 "	88· "
Aluminium,	5·2 "	6·3 "
	100·5	102·1

The writer is indebted to Messrs. H. Y. Castner, Douglas Dixon, and others for suggestions and information useful in the preparation of the foregoing pages. He especially desires to acknowledge the kindness of the Cowles Electric Smelting and Aluminium Company, which furnished not only valuable information, but many specimens of their products for the purposes of this investigation.

THE STEREOSCOPE AND ITS APPLICATIONS.

BY PROF. CHARLES F. HIMES, Ph.D.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 14, 1887.*]

At the Eighth Meeting of the British Association for the Advancement of Science, August, 1838, a paper was read by Prof. Charles Wheatstone, accompanied by an instrument illustrative of it, which involved in so high a degree the elements of novelty and great intrinsic scientific value, that it was received with most decided manifestations of pleasure and surprise. The subject of the paper was, "Binocular Vision, and an Instrument for Illustrating its Phenomena," which latter was called by him a stereoscope. The reception accorded the paper and the instrument, and the importance attached to it, can be most briefly placed before you, by an abstract from the proceedings of that body, which I will read from the *American Journal of Science* (**35**, No. 2, p. 295), giving the opinions of two representative men, as follows: "Sir David Brewster feared that the members could scarcely judge

from the very brief and modest account given by Prof. Wheatstone, of the principle and of the instrument devised for illustrating it, of its extreme beauty and generality. He considered it one of the most valuable optical papers which had been presented to the Section. He observed that when taken in connection with the law of visible direction in monocular vision, it explains all those phenomena of vision by which philosophers have been so long perplexed, and that vision, in three dimensions, received the most complete explanation from Prof. Wheatstone's researches. Sir John Herschel characterized Prof. Wheatstone's discovery as one of the most curious and beautiful, for its simplicity, in the entire range of experimental optics."

Now, although the instrument, as is apparent, could not but be of great general interest outside of purely scientific circles, its application seemed so hedged about with limitations, that it hardly promised to become a popular instrument. But about the same time, Daguerre made the announcement of his great discovery, which not only widened the field of application of the stereoscope, by bringing within its range many subjects previously hopelessly excluded, but in its subsequent development so completely supplemented Wheatstone's discovery, by its cheap multiplication of pictures of all objects, of mathematical accuracy, that the stereoscope became the scientific sensation of the day, and found its way into the parlor as well as the study. It seemed to have acquired for itself a permanent place in almost every intelligent household.

Now, in the treatment of this subject this evening, it seems that the best disposition of the time at our disposal can be made by considering, first, rather hurriedly, the principles underlying and explanatory of the instrument, and then as many of the most characteristic applications as the time may allow, with incidental discussion of theoretical considerations and disputed points, as they may present themselves. Just at this point, I desire also to state that as many statements in the nature of the case are not susceptible of confirmation or illustration, by means of flat drawings, reproduced upon the screen, a number of stereoscopic illustrations will be open to examination, with the aid of the instruments, at the close of the lecture, to such as may desire.

I have given Prof. Wheatstone's paper the prominence I have,

because the whole subject seems to develop most naturally by inquiry into his merits in this connection. What, then, was his discovery? What is his claim? I think I can safely say that it is broader than the simple invention of the instrument, which he called a stereoscope. It was the conception which preceded the instrument, which suggested it, which, in fact, demanded it, and called it into existence, that had the prime element of novelty in it. This statement may almost seem superfluous, but I make it here at the outset, because Sir David Brewster, apparently forgetful of the generous tribute to Prof. Wheatstone, which I was careful to read a few moments ago, subsequently made labored efforts to restrict the claim of Prof. Wheatstone to the invention of an instrument, and that an instrument which, as he at the same time contended, is inferior to the lenticular stereoscope of his own invention, now in popular use. What, then, in brief, was the state of knowledge and the theory of vision at that time? The physical explanation of vision by the formation of a distinct image of external objects upon the retina of the eye was entirely satisfactory. The eye, optically considered, was regarded as a camera obscura, with the retina as the ground-glass. This instrument has become so common to-day, by the rapid spread of amateur photography, that familiarity with it may be assumed without further explanation. There were, to be sure, some remaining difficulties to be explained away, but they were often manufactured, and rather physiological or psychological in character. The notable one, how inverted retinal pictures can occasion erect vision of objects—is closely related to our subject by the *law of visible direction*, alluded to by Sir David Brewster, which explains it. A law which, simply stated, is that visible points are referred back to positions in lines along which the light from them finally strikes the retina, or that we see points in the direction in which light from them strikes the retina. But the consideration of vision with two eyes introduced new complications, and perplexing questions peculiarly its own. Having two eyes, each evidently receiving its own retinal picture, we nevertheless receive but a single impression, or we see the object single. How, where, when do these two impressions fuse into one? But on further consideration, the difficulty is intensified. The retinal pictures in the two eyes are not identical, but in the nature of the case must be essentially

different—as different as the drawings of an object made from two different points of view, as distant from each other as the interocular distance. It is certain, then, that our clear, unconfused single mental impression exists in spite of the dissimilarity of the retinal pictures of the two eyes. But upon still further investigation, it is found, that not only does no confusion result from these separate dissimilar pictures presented to the mind, as it were, at the same time, but, what is still more remarkable, that from these dissimilar retinal impressions, and by reason of their dissimilarity, no doubt, we have more definite perception of external objects. In whatever way explained, the fact was indisputable that there results from this dissimilarity of retinal impressions such a perception of distance and, consequently, of form, that it seems, as some contend, an added direct perception of distance, and not the result of an unconscious judgment, based upon additional data furnished by the two eyes. There can be no physical explanation of this seeming fusion of dissimilar retinal impressions, and the resulting additional perception. It must be clearly physiological or psychological, or both. But although assent is generally readily given to the fact just stated, its importance in this connection is such that it may be allowable to emphasize it by testing it by an experiment, something, too, in the nature of a quantitative experiment. Any two persons will answer the purpose. (Two gentlemen presented themselves, and were furnished with lead pencils.) Now, if you please, take a position opposite each other, about an arm's length apart. Let the gentleman on the left hold his pencil in a vertical position, about half an arm's length from his body, and the gentleman on the right hold his similarly, but with its lower end several inches higher than the upper end of the other pencil; and now, with one eye closed and the head held in a fixed position, let him move his hand forward until the point of his pencil seems to be directly above that of the other pencil, and now bring it down upon it. The result shows how erroneous the estimate; with both eyes open, there is no difficulty in bringing them together. Repeat the experiment as often as you please, the only variation will be an accidental one in the magnitude of the error. I held this newspaper screen up between the parties during the experiment, so that no other criteria of distance might accidentally be introduced, more particularly the movement of the arm.

We cannot with one eye open, with certainty, bring the tips of the index fingers together at arm's length, or snuff a candle. Indeed, we often find ourselves almost with a feeling of a loss of clear vision when we are obliged to estimate distance without being able to bring both eyes to bear upon the same point. It is clear now, I think, that no picture of an object, however accurate in drawing, or faultless in all respects, can produce the same infallible impression as that produced by the object itself, which furnishes us, through the two eyes, two dissimilar pictures of the object. All the criteria of distance and form that can be introduced into a drawing are, in the nature of the case, monocular. They may be manipulated and reinforced, but not changed in character, and by none of them, nor by all of them together, nor by any treatment of them can an infallible judgment as to form be reached.

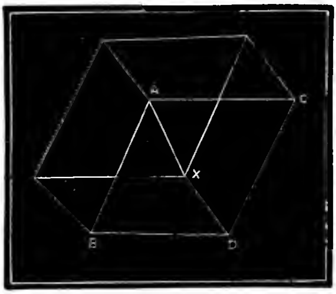


FIG. 1.

Our judgment in such cases is controlled, to a great degree, by conditions and facts external to the drawing. This is another of those statements readily acceded to, but hardly accorded its full practical importance, especially in this connection. To impress it more decidedly, I will bring before you a few illustrations, which also have an additional interest of their own. In his treatise on the Stereoscope,* Sir David Brewster devotes considerable space to what he styles "a very remarkable illusion," a "puzzling phenomenon," to which his attention was first called by Prof. Neckar, of Geneva. The diagram (*Fig. 1*), now on the screen, he remarks, was so drawn that A should appear nearest the spectator, and the face $A\ B\ C\ D$ foremost, and x farthest from him. But he says, on

* *The Stereoscope*, p. 228.

looking at it repeatedly, the apparent position of the rhomboid is changed, x and its face will appear in front, and A and its face will appear more remote, and give the solid a different inclination. Any of you can readily test these statements by means of the diagram on the screen. You can cause A or x to come to the front, or to recede at will. Now this results from the simple fact that the two solids are represented by the drawing. Sir David says it was drawn so that A should appear in front. That may be so; but there is nothing in the drawing to justify the statement. Had the artist intended x to appear in front, he would have drawn precisely the same figure. In reviewing this book some years ago, this puzzle recalled some early ones of my own, and I suppose of almost any boy, entering upon solid geometry. But doubtless you all see first the solid with A in front. This I would explain by the fact, that that solid appears in a natural position, fully supported; whilst the

FIG. 2.

other solid, represented when x is in front, is in an unnatural, unsupported, I would almost say, impossible position. That solid that has the most usual position, is first suggested, and I have no doubt that this particular diagram arrested the attention of Prof. Neckar, and afterward of Sir David Brewster, simply because of the accident, that it represents two solids differing so widely in this respect. I have simplified this in the diagram now on the screen, (*Fig. 2*), to which I will call attention again in another connection. In either of the diagrams it will require very little effort to cause either of the squares to appear in front of the other. There is no reason, in the nature of the case, why one should appear in front rather than the other. There is another diagram illustrative of this point frequently referred to as Schroeder's* steps, (*Fig. 3*), that

* *Poggendorff's Annalen*, **105**, 298. Helmholtz, *Handbuch der Physiologischen Optik*, p. 626.

it will be presented for an instant. At first glance, the outline and the shaded drawings, doubtless to every one represent steps in their most natural position, but by a very little effort they can be converted into overhanging steps.

But it might be said that a monocular picture of the *object itself* upon the retina of a single eye, should also be capable of this two-fold interpretation. That in looking at an object with one eye, we should receive no infallible impression as to its form. Neither do we. But in most cases the prepossession given by other circumstances renders it impossible to recognize other than one. But if an object is taken, in which this difference in naturalness or usualness, so to speak, of the two objects represented is reduced to a

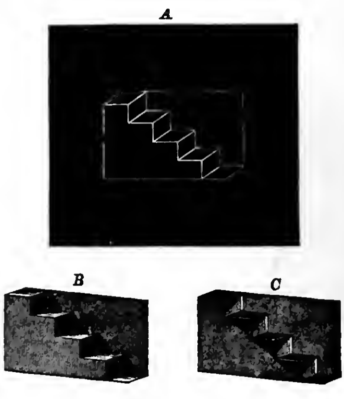


FIG. 3.

minimum, we will find how readily we can be deceived. The photograph upon the screen seems to represent a medallion in relief. I do not hesitate to assert, that no one is able to imagine it to be anything else, and yet it is a photograph of a mould I hold in my hand. What is true of the photograph is equally true of the retinal impression formed by the object on one eye. When looked at with one eye, with the head immovably fixed at the distance of several feet, it will invariably and persistently appear as a relief, and I think simply because objects of the kind are far more frequently met with in relief than as intaglios, and we cannot emancipate ourselves from the effect of this circumstance. Both eyes, however, soon settle the true character of the object. It is possible that one accustomed to work in plaster, as familiar with

moulds as the casts made from them, could see it as readily as a mould as a cast.

It may be admitted that this superiority of binocular over monocular vision, and the essential conditions of it were recog nized before Prof. Wheatstone's paper was read, but he seems to have been so impressed with these facts, that it occurred to him, as there is no reason to believe it occurred to any one before him, that, if he could, by any means, reproduce the conditions of binocular vision by means of flat drawings, he could also produce the irresistible impression of solidity of form; that is, if he could, by any means, simultaneously produce in the two eyes retinal impressions of such a degree of dissimilarity as an object would produce when looked at with both eyes, a perfect binocular illusion of the object would be produced. If, for example, he could present

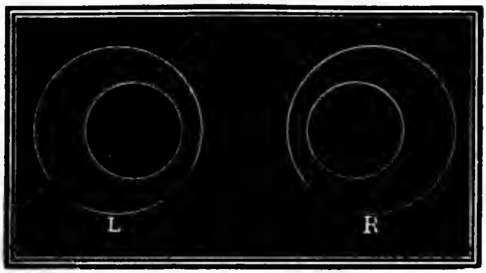


FIG. 4.

to the left eye the picture of the frustum of a cone as seen by that eye, and at the same time the picture of the same frustum to the right eye, as seen by that eye, as in the diagram (*Fig. 4*), the same effect of perception of complete relief should be produced as by the presentation of the object itself. But he did more; he demonstrated experimentally and conclusively the correctness of his reasoning. But an apparently insurmountable difficulty is encountered in any attempt to look at the same time at one picture with one eye and at another with the other eye. It lies in the fact that as we see but one point of an object with greatest distinctness at a time, we direct both eyes invariably to the same point, and thus in passing from point to point roll the eyes inward, if to a nearer point, outward, if to a more remote point. In other words, we direct the optic axes to that point, and cause its image to occupy the place of

most distinct vision in each retina. At the same time, we accommodate the eye—adjust it focally to distinct vision of this point.

It is this play of the optic axes, this variation in the angle formed by them, or, if you please, the muscular effort required to produce it, in turning from one point of an object to another, that, in some way, seems inseparably connected with our infallible binocular perception of distance. Whether by reason of it, this perception is original, antecedent to experience, according to the so-called *nativistic theory*, or whether it is dependent upon it simply as upon a peculiar criterion of judgment, and is wholly the result of experience, according to the *empiristic theory*, has been a matter of great dispute. No one has more clearly enunciated the latter theory than Bishop Berkley, whilst on the other hand Sir David Brewster has as warmly disputed it. Now, although closer investigation forces to the conclusion, that simple play of optic axes will not wholly account for binocular perception of distance, yet the great preponderance of opinion is in favor of the view that this perception of distance is not primary, but is an unconscious visual judgment. It would hardly repay to give much time to the discussion of this point. I will simply call attention to a fact, that seemed almost conclusive to me upon investigation of it some years ago.*

New-born infants not only have no perception of distance, but seem to have no tendency to move their eyes in concert. As a rule, they appear cross-eyed, without, however, a decided in-squint or out-squint, but rather with a peculiar working of the eyes, resulting from want of concert in their movements. This vanishes after a short time, and the unvarying habit of convergency accompanies the acquisition of perception of distance.†

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* *American Journal of Photography.* Vol. v, p. 114. (1862.)

† Any argument against this view from the analogy of the lower animals must be received with great caution. Many of the lower animals possess only monocular vision on account of the position of the eyes, which precludes concerted use. The absence, too, in almost all lower animals of a retinal area of most distinct vision removes the incitement to concerted action of the eyes. The argument from the young of birds, by Adam Smith, seems to have more weight conceded to it by Sir William Hamilton than it merits, especially when it is remembered that most birds, other than the carnivorous, have their eyes so situated that they cannot be used in concert. They may be often observed to turn the head and look steadily with one eye at an object, making a purely monocular study of it.

Now, when we look at a stereograph in ordinary vision, both eyes look at the right-eye picture, or left-eye picture, at the same time; the axes intersect in a point in the plane of the paper, and, at the same time, both eyes are accommodated to the plane of the paper, so that when we require the right eye to look at its half of the stereograph, and the left eye to look at its half, at the same time, we call for a violation of this consensual habit of convergence of the axes and accommodation of the eyes to the same point. For, whilst the eyes would be accommodated for distinct vision to the plane of the paper, the point of intersection of the axes would be more remote, if indeed, as we shall see after awhile, they intersect at all. But, whilst this dissociation of invariably associated optical adjustments is difficult, it can be accomplished by any one

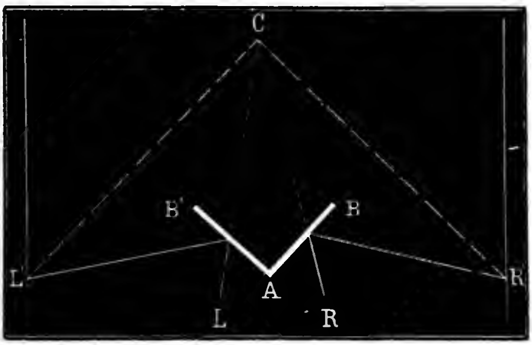


FIG. 5.

with some effort and some patience, and when, upon looking at a stereograph, the effort is successful, the picture springs out into inimitable, almost magical, relief, as we have reason to believe first happened to Wheatstone.

But Wheatstone devised an instrument to aid in presenting the dissimilar pictures to their respective eyes at same time without this violation of habit. Optically it is extremely simple in principle. In the diagram, (*Fig. 5*) L' and R' are similar points in the left-eye and right-eye pictures, L and R, the left and right eye, and $A\ B$ and $A\ B'$ plane mirrors. The rays of light from R' will enter the right eye as if proceeding from C, and those from the similar point L' enter the left eye, as if from the same point C, and accommodation and convergence of the axes will be to the same

point, when these similar points of the two pictures are looked at. As it is generally stated, the instrument superposes the two pictures. Now, there are many instruments by which this superposition, so to speak, may be accomplished. Refraction suggested itself to Sir David Brewster instead of reflection as employed by Wheatstone. He devised the form of stereoscope now in general use, which the word suggests to most persons, in which lenticular prisms replace the mirrors, thus affording not only a more compact and convenient instrument, but one that permits both pictures to be mounted upon the same card as in the ordinary stereograph. There are many other stereoscopes, in great variety, all interesting, many of them curious, but as a rule they only serve to demonstrate that the same effect of superposition can be produced in still another way. There is, however, one adjustment of the ordinary stereoscope, of very decided value, but which is invariably wanting. It is an adjustment of the lenses to the variable distance between the eyes of different individuals, and at the same time to the slight variation in distance of similar points in stereographs in the market, or, if they are properly mounted, we might say to their breadth. Much of the dissatisfaction and want of comfort in the use of a stereoscope in many cases is due almost exclusively to this want of adjustment to the interocular distance of the individual, accomplished by sliding the prisms nearer to or further from each other. Although this addition would be comparatively inexpensive, there seems to be so little popular demand for anything beyond the simplest and cheapest forms, that they are not kept in the market even after advertised. One recently devised by Prof. Le Conte Stevens,* having this adjustment, and many others valuable in its employment for investigation, I regret to say, cannot be obtained from a leading firm which has largely advertised it.

(*To be continued.*)

* *American Journal of Science*, March–April, 1882.

A NEW METHOD TO DETERMINE THE MOON'S MASS CORRECTLY, FOLLOWED BY A DISCUSSION UPON THE THEORY OF TIDES FULLY IDENTIFYING THE PHENOMENON UPON DYNAMICAL PRINCIPLES.

BY L. D'AURIA.

(*Continued from Vol. cxxiii, page 334.*)

[*Presented in a Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, February 25, 1887.*]

The definition already given of the values of D and ω in equation (1), is not sufficient when we consider that even in quadratures the mass M may be found under the influence of an accelerating force in the direction μM, and which should be taken into account in the first of our fundamental equations. But remembering that such force must be zero at the time when M has acquired its maximum velocity in that direction, and that this takes place when M is at right angles, or nearly at right angles, to the line of apsides, our fundamental equations remain the same, provided the values of D and ω are taken in quadratures occurring with the sun on that line. Therefore, equation (1) can be used for these particular values of D and ω only, and no others, and which cannot be observed but twice every nine years, owing to the motion of the lunar apsides.

Let D_m, ω_m represent the values of D and ω, taken when M is at right angle to the line of apsides; α, the inclination of this line with respect to the sun; ω_1, the angular velocity of the earth and moon around the sun; then the sun's disturbing force upon M in the line μM will be found very approximately expressed by $3\ M \omega_1^2\ x \sin^2 \alpha$. In fact, if we denote by a, the sun's distance from the common centre of gravity of the earth and moon, and by S, the sun's mass; then, while M is at right angle to the line of apsides, its distance from the sun will be $(a + x \sin \alpha)$; and its centrifugal force around the sun will be $M \omega_1^2 (a + x \sin \alpha)$. The sun's attraction upon M will be—

$$\frac{c\,S\,M}{(a + x \sin \alpha)^2};$$

and observing that $c\,S = a^3 \omega_1^2$, the sun's disturbing force upon M will be—

$$M \omega_1^2 (a + x \sin \alpha) - \frac{M a^3 \omega_1^2}{(a + x \sin \alpha)^2},$$

or,

$$M\,\omega_1^{\,2}\,\frac{3\,a^2\,x\sin a + 3\,a\,x^2\sin^2 a + x^3\sin^3 a}{(a + x\sin a)^2}.$$

Since x is very small with reference to a, this expression can be reduced to $3\,M\,\omega_1^{\,2}\,x\sin a$; and its projection upon the line $M\,\mu$, which represents the sun's disturbing force in that line, will be $3\,M\,\omega_1^{\,2}\,x\sin^2 a$.

Now we have the following equations for the determination of the moon's mass; viz.:

$$\frac{c\,M\,\mu}{D_m^{\,2}} = M\,\omega_m^{\,2}\,x + 3\,M\,\omega_1^{\,2}\,x\sin^2 a; \quad M\,x = \mu\,(D_m - x);$$

which offer—

$$\frac{M}{\mu} = \frac{\rho^2\,g}{D_m^{\,3}\,(\omega_m^{\,2} + 3\,\omega_1^{\,2}\sin^2 a) - \rho^2\,g} \tag{3}$$

If we designate by D_{mq}, ω_{mq}, the values which D_m, ω_m, assume in quadratures; that is, when $a = 0$, we have

$$\frac{M}{\mu} = \frac{\rho^2\,g}{D_{mq}^{\,3}\,\omega_{mq}^{\,2} - \rho^2\,g} \tag{4}$$

which in the limitations already assigned to D and ω in equation (1), are identified.

Comparing equations (3) and (4), we get the remarkable relaticn—

$$D_{mq}^{\,3}\,\omega_{mq}^{\,2} = D_m^{\,3}\,(\omega_m^{\,2} + 3\,\omega_1^{\,2}\sin^2 a) = \text{const}; \tag{5}$$

from which can readily be concluded that the term $D_m^{\,3}\,\omega_m^{\,2}$ in quadratures becomes a maximum. Hence, if D and ω are mean values, we have, most likely,

$$D^3\,\omega^2 < D_{mq}^{\,3}\,\omega_{mq}^{\,2},$$

which would account for the rather deficient value of the moon's mass found in our foregoing computations. However, not until the constant (5) has been properly determined, we can by any means pronounce the last word about the value of the moon's mass; and it is to be hoped that astronomers, in the interest of their science, will soon arrange for a series of concerted observations to accomplish this result.

With this, the first part of our paper is concluded, and we shall now enter upon the theory of tides.

(*To be continued.*)

BOOK NOTICES.

THE LIFE AND WORK OF THOMAS GRAHAM, D.C.L., F.R.S. Illustrated by sixty-four unpublished letters, prepared for the Graham Lecture Committee of the Glasgow Philosophical Society, by Dr. R. Angus Smith, LL.D., F.R.S. Edited by J. J. Coleman, F.I.C., F.C.S. Published by John Smith & Son, West George Street, Glasgow. 1884.

In 1878, some leading manufacturing chemists of Glasgow subscribed a sum, which was put at the disposition of the Chemical Section of the Philosophical Society of Glasgow, for the encouragement of original research. They associated this idea with the name of the most distinguished Glasgow chemist of whom they could think, and that was Thomas Graham. Dr. R. Angus Smith was invited to deliver a lecture on the life and activity of Graham, and he agreed to do so, making the basis of his sketch from letters, in his possession, of Graham to his relatives and friends, from his first year of emancipation from the duties of a scholar, about 1826, to a letter to Miss Graham Pau, of February 11, 1863. In these letters there is much that interests the general public, chiefly from the fact that it proves how human even great men are.

It would be strange if this should need further confirmation, or if the confirmation should elicit interest, but it is so. His sister Margaret and his mother have the lion's share of the letters. Side lights like the following, on other great men, strike their worshippers unpleasantly. "Edinburgh, July 7, 1826. Sir Walter '[Scott]' must have been a calculating genius. It turns out that he was almost sole proprietor in the printing establishment of Jas. Ballantyne & Co., who have failed, so that he intended not only to profit by writing the novels, but also to have a good share in the profits of printing them. Ballantyne was little more than his servant," etc. Quite droll is the following:

"EDINBURGH, October 15, 1826.

"*My dear Mother:*

"My operations have been interrupted for two or three days. I find a room which Miss Cameron occupies at night as a sleeping-room, and which is otherwise unoccupied, forms a very good laboratory for the experiments in which I am engaged, and likely to be engaged for a considerable time. They are doing very well—"

At this period commenced the anguish at the accidents which prevented his articles from being printed in the *Quarterly Journal of Science*, and the *Annals;* the gratification at a perfunctory politeness or two; the satisfaction at being temporarily installed as "Prime Minister" of Chalmer's *Miscellany*, etc.

It is hard to realize that such things made the same impressions on men of Graham's mould as on lesser clay. He wishes to go to London. All Britons do.

Following the letters is a short biographical sketch by Dr. Smith, in which we find that Graham early got into a "very languid mode of life. * * *

He was often in great straits for want of money. Once he required a silver crucible to make some experiments for a commercial firm, but he could not buy one, and *he was refused credit* (*!*)" etc.

The biography, which succeeds this short sketch, is very ill-arranged, and skips about among subjects and dates in a confusing manner.

The appendix, or "critical remarks," to the foregoing pages of Thomas Graham, being a preface by Dr. Angus Smith to *Physical Researches of Thos. Graham*, published for private circulation by Dr. R. Angus Smith and James Young, in 1876, is one of the best treatises extant on the general subject of atoms, and the extent to which the ancients (and to some extent the "intervening thinkers") anticipated modern views. P. F.

THE NEW SOUTH. A Description of the Southern States, noting each State separately, etc. By M. B. Hillyard. *Manufacturers' Record* Company, Baltimore, Md. 1887.

This is an "offering of love to the South," well deserved and ably executed, in an 8vo volume of nearly 500 pages, wherein her wonderful progress in agriculture, arts and sciences, during the past fifteen years especially, is shown and supported by convincing data. We regret that it is impossible here to give proper extracts from the last, but a partial *résumé* will aid in affording a fair idea of the changed condition and the great advance. In all the Southern States, introduction of free labor, more diversified production, and use of improved agricultural machines from the Northwest and North, have largely contributed to the following change, in eighteen years, in agricultural production:

	Bushels.		
	Corn	*Wheat.*	*Oats.*
1885,	470,776,000	53,526,000	78,675,000
1868,	354,124,000	31,822,000	32,583,000
Increase,	116,652,000	21,704,000	46,092,000

The total amount of coal mined in nine Southern States in 1870, was 3,193,190 tons, and in 1885 it had advanced to 12,511,539 tons. The increase here noted in the utilization of cotton-seed in eleven States, is for seven years only, viz.:

	Capital.
At the close of 1880, there were 40 mills,	$3,504,500
" " 1885, " 146 "	10,792,450

The number of pounds of cotton raised in 1886 was nearly double the quantity of 1870; and in nothing, perhaps, has the South advanced so much as in its manufacture of cotton. In January, 1887, the number of cotton mills in thirteen Southern States was 353, as against 180 in 1880, being a gain of 173 mills. North and South Carolina, Georgia and Tennessee are the States showing most increase in this respect, during the past seven years, viz.:

	1880. Per U. S. Census.		1886.	
	Looms	*Spindles.*	*Looms.*	*Spindles.*
Georgia,	4,713	200,974	8,648	385,613
North Carolina,	1,960	102,767	3,118	257,576
South Carolina,	1,776	92,788	4,579	224,732
Tennessee,	1,068	46,268	1,528	117,444

In 1880, the South had but 6·7 per cent. of the 10,635,435 cotton spindles in operation in the United States, but now the proportion is nearly eleven per cent.

The increase in production of iron is one of the most surprising of all; the world has never shown a similar record of progress, for six years, in any mineral department.

	1880.	*1881.*	*1882.*	*1883.*	*1884.*	*1885.*
Alabama, tons of iron,	77,190	98,081	112,765	172,465	189,664	227,438
Virginia, " "	29,934	83,711	87,731	152,907	157,483	163,782
Tennessee, " "	70,873	87,406	137,602	133,963	134,597	161,199
Total,	177,997	269,198	338,098	459,335	487,744	553,419

Alabama, with Birmingham as chief centre of production, is becoming one of the greatest iron producers of the world; and one of its principal advantages is the cheapness of production. It is stated that, at Birmingham, $8 per ton covers all expenses, and Bessemer steel can be made there for $10.50 per ton.

Passing over much that might be shown of improvement in other industries such as saw, planing and sash mills, silk, hemp, etc., and the existence of vast mineral deposits, including phosphates and marls, as yet only slightly developed, the increase in mileage of railroads, an immense amount of water-power running to waste, and large tracts of virgin forest still standing in many portions—we close this imperfect summary by some remarks from the last part of the introduction of this interesting book:

"To the writer, no aspect of Southern progress is so marked and cheering as the hopeful, erect, self-assertive, industrial spirit of the South. * * * Time was when she had almost no courage to undertake manufacturing. The few cotton mills could not sell their goods to the Southern trade direct, but had to send them to Northern salesmen, who sold them to the merchants within the shadow of the mill where they were made. The South thought her manufactures were next to worthless. She must needs have New England goods. But this has passed away now; she believes in her capacity to do. It is not the rash and presumptuous confidence of unreflecting imbecility or inexperienced immaturity; it is a courage based on results. * * * Her aggressive and experimental spirit will carry her into new fields of endeavor, where there are many opportunities for conquest." N.

LUFTDRUCKBREMSE, SYSTEM CARPENTER. 1884. By J. Fairfield Carpenter, Berlin.

This book contains a full description of the Carpenter air brake for railway trains, which is, perhaps, the most formidable competitor to the Westinghouse air brake, so well known in this country.

The adoption of this system, after a lengthy competitive test, upon the railroads operated by the Prussian Government, is regarded by the inventor as an endorsement of the claim of superiority over other systems.

The various modes of application to engines and cars, as well as the details, are presented by eleven well-executed plates, accompanied by detailed description. H. B.

SCIENTIFIC NOTES AND COMMENTS.

PHYSICS.

An Optical Illusion.—A number of years ago, I observed the following illusion. When the eye watches for some time, in complete darkness, a motionless object of small diameter, and feebly lighted, it very often happens that this object appears clearly to move with a certain rapidity in a specific direction. This phenomenon, when it takes place, is very striking, and almost all upon whom I have tried to reproduce it have verified it. It is an appearance analogous to that of a shooting-star, but less rapid. The angular rapidity of the apparent displacement of this object has appeared to me to be between 2° and 3° per second. The direction of displacement is variable. The object appears oftenest to progress in a curved line upwards or outwards, but this direction may be quite different from either. Sometimes the object follows successively different courses; it may describe curves or zigzags. The total extent of the displacement varies; it may attain and exceed 30°. In reflecting upon the possibilities of this illusion, I have thought at first of an unconscious movement of the eye. This explanation must be rejected: the eye remains fixed as well as the object. Indeed, the form of a group of little points very near together may be given to the object, and these cannot be seen except by the centre of the retina. Now, under these conditions the illusion persists; besides, the experiment succeeds with both eyes, and a simultaneous displacement, exactly symmetrical and quite extensive, of the two eyes would not pass unperceived. The illusion, then, does take place when an eye at rest looks fixedly at an object at rest. I have studied, moreover, to see whether the point of departure was not a special position of the eye in relation to the head, which would produce an abnormal, tonic contraction of the muscle corresponding to the apparent sense of displacement of the object; but the different positions I have given to the eye have not prevented the phenomenon from appearing, and have not introduced anything special into it. A fact which may throw some light on the production of this illusion, is that it is possible to provoke a voluntary, apparent displacement of the object in a given direction. It suffices for this, to think of seeing another object, or of accomplishing an act in the desired direction. For example, with my eye at the eye-piece of the dark chamber, which serves me for these experiments, I think of picking up a pin or book on the floor, and I see the object not always, but generally, move down: if I think of the chimney, on the roof which faces my window, the object rises, etc. I repeat it, and there comes a distinct sensation which everybody can obtain. It has been objected that my eye accomplished the supposed movement itself, but this is incorrect; I have assured myself of the contrary. Moreover, it is easy to see that, as the eye looked up, the object must, on the contrary, appear to descend, and vice-versa. Under what conditions do we ordinarily feel that an object moves when the body and head are immovable and we have no

observation mark in the field of vision? (1.) If the eye is at rest, the image of the object moves on the retina, and brings in play a tendency of the eye to move to follow the object. (2.) The image of the object may remain fixed in the middle of the retina, but then the eye moves really to test this fixity, and we perceive this movement of the eye. Now, in our experiment we have indeed this condition, fixity of the retina, but the muscular contraction is missing. Since we perceive really a displacement of the object when we think of a displacement of the eye, it follows then that the idea, as has been said, must be a beginning, a precursor of the motor act, a motor effort not followed by effect. The illusion may then be explained, when it is not provoked by the observer, by unconscious efforts producing themselves in the brain in a manner similar to the association of ideas. In giving this explanation, I wish it understood as a simple hypothesis.—*Comptes Rendus, May 24, 1886.* C.

CHEMISTRY.

BLEACHING ALUMINA COMPOUNDS. *Dingler's Polyt. Journal*, **263**, 164.)—Wilson's "bleaching fluid" is prepared by mixing clear solutions of sulphate of alumina and chlorinated lime—sulphate of lime is precipitated and aluminium hypochlorite remains in solution together with aluminium chloride. R. Weiss (German patent, No. 38,084, April 30, 1886) prepares alumina compounds of stronger bleaching power by causing chlorine gas to react upon aluminates, especially those of sodium, calcium and magnesium. The compounds can be obtained in liquid as well as in solid condition. In the first case, chlorine is passed into a suitably diluted solution of sodium aluminate, or into water in which calcium or magnesium aluminate is floated. In the latter case, chlorine is absorbed by layers of the dry aluminates, and the bleaching compound is obtained in a powder similar to chlorinated lime. It is claimed for these chlorinated alumina compounds, that they act within an extraordinary short time by yielding ozonized oxygen upon mere exposure, without subsequent acid-treatment, and that the fibre is much less corroded than by ordinary "bleach." O. L.

ON A GRAVIMETRIC METHOD OF ESTIMATING TANNINS. H. R. Procter (*Jour. Soc. Chem. Ind.*, **6**, 2.)—The author finds the "tan tester" of Müntz and Ramspacher, which, in various modifications, consists of a small filter press, by means of which the liquid to be tested is forced through a piece of wet rawhide, to have failed in practice, the variations by different investigators having been as high as thirty per cent.

It occurred to him that a modification of the process of Messrs. Simand and Weiss (*Dingl. Polyt. Jour.*, **260**, 564,) would approach perfection. An argand lamp-chimney has a perforated cork, covered with muslin, put in its small end and pushed down until it rests on the shoulder near the base; hide powder is then filled in until it occupies a space of about 50 c. c.; another perforated cork, covered with muslin, is pressed down on the powder. The chimney is cut off even with this second cork, and a small tube fitted into the perforation. The wide end of the tube is now dipped into distilled water

until the powder becomes moistened, when the chimney is removed, reversed and fastened in a convenient place. The apparatus now has the appearance of a small percolator, the wide end of the chimney serving the purpose of a reservoir. A strong solution of tannin is now poured in, and allowed to slowly percolate through the powder, leaving its tannin in combination. The object in dipping the larger end into distilled water first, is to moisten the powder, so that the tannin liquor, in its passage, is evenly distributed through the powder, instead of forming channels and running through uncombined. Definite volumes of the liquid are evaporated before and after passing through the hide powder, the difference giving the amount of tannin.

The most serious objection to this process is that gallic acid is likewise absorbed by the hide powder, a one per cent. solution losing seventy-eight per cent. of the total. This condemns the method for rigid scientific work when gallic acid is present, but the author hopes to overcome this difficulty by removing the gallic acid, or preventing its absorption by the hide. Glucose is also absorbed, but dextrine appears quite indifferent. Distilled water dissolves a small quantity of the hide, so that allowance must be made for that.

H. T.

THE COLORING MATTER OF THE RED AND YELLOW DAHLIA.—Roland Williams (*Journal of Society of Dyers and Colorists*, **3**, 2.) The author has prepared solutions of these two varieties, by boiling the flowers in water and using the decoctions for dye testing. Wool and silk were colored without mordants, but on first mordanting with alum, or tin salt, wool, cotton and silk were all beautifully colored.

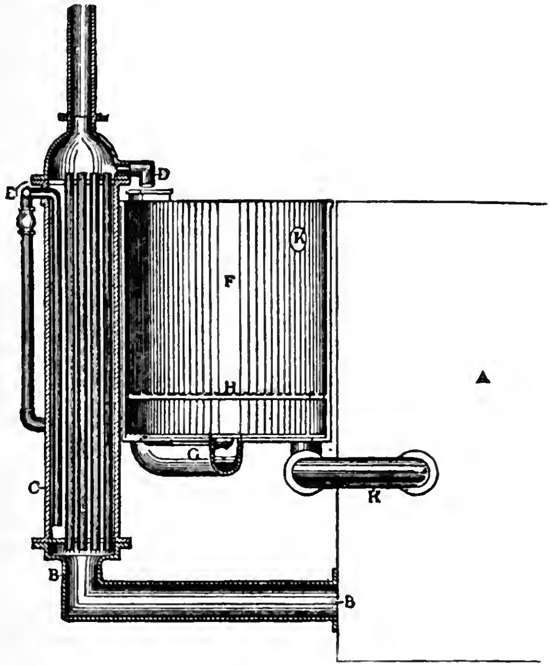
With alum, the color produced was a golden brown, the solution from the red dahlia giving the darker shade. With tin salt the red produced a cinnamon brown, and the yellow a good yellow shade. All of these shades, whether obtained from the red or yellow flowers, were "fairly fast both to light and soap."

The solutions were so sensitive to alkalies that they may be used as indicators in acidimetry, a fact which the author proved by actual experiment.

H. T.

A NEW METHOD AND APPARATUS FOR EXTRACTING DYEWOODS FOR IMMEDIATE USE IN DYEING, ETC. J. B. Wilkinson (*Journal Society of Dyers and Colorists*, **3**, 18.)—The apparatus consists of the dye cistern *A*, the extractor *F*, and the cylindrical vessel *C*. From the bottom of *A* a current of water comes into *B*, through which it passes to *C*. This vessel is for the purpose of causing a current and raising the water through the pipes in *C*, from *B* to *D*. This is accomplished by having the pipes in *C* surrounded by steam. *E* is a flange, which prevents the steam getting any higher, the pipes being open at the top. The current of water rises above these, and passes forward into the vessel *F*. This vessel contains the chipped wood—logwood, fustic, etc. The water passes down pipe *G*, outside the vessel, and is delivered from underneath, entering between the bottom of the vessel and the perforated grate *H*, which sustains the dye materials. The water which

is, perhaps, a trifle above the hot water point, passes up through the wood, and down another pipe, *K*, then into the dye vessel. The apparatus is best arranged with two extractors, the cylinder can raise the liquors for both, and one can be emptying and filling while the other is in use. The advantages



claimed may be briefly summed up as follows: (1) Saving of labor, fuel and time; (2) dispensing with the use of cages and bags; (3) freedom from small pieces of wood and bags; (4) more thorough extraction of the color from the dye woods. H. T.

A Delicate Reagent for the Detection of Active Oxygen.—C. Würster (*Berl. Ber.* **19**, 3,195), finds that tetramethylparaphenylenediamine is an exceedingly sensitive test for active oxygen. In neutral or acetic acid solution, this substance assumes an intense violet-blue color by the action of oxidizing agents. By further oxidation, the blue color is changed to red, and finally the liquid is bleached, owing to the formation of a colorless compound that is not easily characterized. Test papers prepared with the compound are made and sold by Schuchardt, of Görlitz, and their great sensitiveness permits the detection of such small traces of active oxygen that Schoenbein's theory, according to which oxygen becomes active in all oxidations, seems to be confirmed. Its presence may be detected in the air, in the neighborhood of flame, in the juices of plants, and even on the human skin. Since all oxidizing agents color the paper violet and finally bleach it, it cannot serve for the detection of isolated active oxygen, but will at once indicate the possibility of

a disengagement of chemical energy from peroxidized molecules. Silver oxide, and the peroxides placed on the moistened paper at once color it violet, thus plumboso-plumbic oxide causes the reaction, while lead monoxide is without effect.

The same author (*loc. cit.* 3,217) proposes a paper prepared with dimethyl-paraphenylenediamine as a reagent for the detection of wood-fibre in paper. The tetramethyl compound is too sensitive for this purpose, because it will assume a violet color by the action of the resin contained in many papers; but the dimethyl compound becomes fuchsin-red by the oxidizing action of the wood-fibre, while it assumes only a pale red by the action of resin. In both cases, the oxidizing action is similar to that of oil of turpentine, whose slow oxidation engenders ozone. The wood-fibre retains much insoluble resin.

W. H. G.

PREPARATION OF CALCIUM SULPHIDE PHOSPHORESCING WITH DIFFERENT COLORS. (A. Verneuil, *Compt. Ren.*, **103**, 600.)—*Violet.*—Twenty grammes of pulverized calcium oxide prepared by treating the shell of *hypopus vulgaris*, are intimately mixed with six grammes sulphur and two grammes starch, and the mixture is moistened with 8 c.c. of a solution of 0·5 grammes bismuth basic nitrate in 100 c.c. absolute alcohol. The mixture is exposed to the air until the alcohol has nearly all evaporated, and then heated to a cherry-red for twenty minutes, in a covered crucible. When quite cold, the upper layer of calcium sulphate is removed, and the remaining mass is powdered and again heated to the same temperature for fifteen minutes. The violet color of the phosphorescence is due to bismuth.

Yellowish-green.—Calcium oxide, 100 parts; sulphur, thirty parts; starch, ten parts, and lead acetate, 0·035 part, furnishes, when heated as before, a sulphide phosphorescing yellowish-green. If the proportion of lead acetate is increased to 0·4 part, the green color disappears, the phosphorescence is yellowish-white and less intense.

Orange-yellow.—The same mixture as before, using 3·5 lead acetate. Calcium sulphide made by reducing the pure sulphate in a current of hydrogen or carbon monoxide does not phosphoresce, and that made by reduction with starch phosphoresces but little. It would follow that pure calcium sulphide is not phosphorescent, and that the phosphorescence is due to small quantities of silica, phosphates, alkalies and magnesium, derived from the shells from which the lime is obtained. W. H. G.

AN APPARATUS FOR THE RAPID PERFORMANCE OF NITROGEN ESTIMATIONS.—M. Raulin (*Bul. Soc. Chim.* **47**, 94) describes a method for rapid nitrogen estimations by Dumas' method. A copper tube, 1·8 metre long and 18 mm. in interior diameter, is surrounded in four places by brass refrigerating tubes, through which a stream of cold water flows. Three different substances for analysis are placed between these refrigerants, and the remaining space in the tube is filled with copper oxide and copper gauze as usual. A stream of carbon dioxide is passed through the tube, and the three combustions may be made in rapid succession. The volumes of gas evolved are compared with that of a volume whose weight has been previously calculated.

A deduction must be made from the observed volume of nitrogen for the nitrogen evolved from the acid in the carbon dioxide generator, and correction is arrived at by observing the volume of gas that collects in a given time before and after each combustion, and noting the time of combustion.

W. H. G.

PHOTOGRAPHIC NOTES.—Fuming sensitized albumen paper with common carbonate of ammonia, instead of with aqua ammonia is highly recommended by Prof. Rood. The sensitized paper salted down, as it were, in a cardboard box with sheets of filter paper, and freshly pulverized carbonate of ammonia, will keep for weeks without discoloration, and is not affected by the salt coming in contact with it. In printing, the paper is backed up with a pad charged with the freshly pulverized salt. C. F. H.

THE NEW WOODBURY photographic tissue, according to Mr. Beach, works very satisfactorily, being easy of manipulation, without requiring any extra operation or treatment with castor oil or kindred substances, whilst the results obtainable are said to equal the finest glass negatives, from which they are not distinguishable, except by the difference in weight and thickness.

C. F. H.

INSTEAD of yellow screens in orthochromatic work, Mr. Debenham coats the inside surface of his lens with collodion stained with aurine. C. F. H.

CRACKS in oil paintings are said to disappear when screens are used in copying on orthochromatic plates. C. F. H.

THE FREQUENT jarring of photographic lenses, by many forms of instantaneous shutters in use, is said by Mr. W. A. French to start the balsam with which the glasses are cemented, and ultimately to impair the efficiency of the lens. C. F. H.

THE POISONOUS PROPERTIES OF HOPS. (*Hopéine.*)—It is well known that the soporific effect produced by beer upon the nervous system is strong in proportion to the amount of hops in its composition. Some English beers made with wild hops from America, being condensed in vacuum, led to the discovery of a narcotic alkaloid contained in hops, and as the plant enters in such small quantities into the manufacture of beer, it was supposed that this alkaloid must have a very powerful action considering the quite sensible narcotic effect of the beverage. By boiling the wort with large quantities of American hops, evaporating in vacuum and treating the residue with alcohol, a solution of the alkaloid of hops was obtained, possessing properties in the highest degree poisonous. It was not possible, however, to extract pure *hopéine*, but later it was separated by exhausting the hops by an acid solution of sugar. It was evaporated in vacuum, treated with absolute alcohol, and the impurities removed by treating with ether, chloroform and benzole. *Hopéine*, as a narcotic, resembles morphine in its effects; it acts, however, more powerfully than the latter when used in hypodermic injections. To the taste, as well as in its reactions and derivations, it presents a marked difference. *Hopéine* is indicated by the following formula: $C^{18} H^{20} NO^{4} + H^{2}O$. It is in the form of a white, crystalline powder, not easily soluble in water,

but quickly dissolved in forty parts absolute alcohol. Perfectly white when pure, it turns slightly yellow when exposed to the air. In decomposing, it emits the odor of hops, but otherwise is inodorous. The salts of *hopéine* are in great part crystalline and soluble in water. They contain from one to five molecules of H^2O, and possess the poisonous properties of the pure alkaloid. On the tongue, *hopéine* produces a burning sensation, which at first hides a decided bitter taste. A small dose of it brings sleep, a large dose produces coma and death by paralysis. The ingestion of even ·05 g. leads to symptoms of poison; ·1 g. is a dose dangerous to man; ·1 g. to ·05 g. will kill animals, such as dogs, cats, etc., in less than four hours. All the antiseptic properties of hops, which have not before been explained, are due to *hopéine*, and it may be hoped that it may find a useful application in the treatment of putrid diseases, if they succeed in killing the microbes in the blood itself by hypodermic injections. Up to this time all attempts in this direction failed, because the known antiseptics could not be injected in quantities sufficient to effect healing without imperilling health or life. *Hopéine* unites antiseptic with narcotic action, and it is the only known alkaloid possessing these two properties in so high a degree. To study the antiseptic powers of *hopéine*, many experiments were tried on fermenting liquids. In every case the microbes perished in less than an hour, and a stronger dose rendered their destruction immediate. The progress of decomposition was arrested, and when the action of germs carried by the air to the liquids under treatment had thus been hindered, fermentation could not be re-induced by a temperature favorable to their development. It can be concluded, after that, that the destruction of the ferments was radical. A mixture of fresh milk and cheese in decomposition curdles and decomposes in a few hours at a favorable temperature, while, by the addition of *hopéine* curdling is produced only after twenty hours, and the odor proving decomposition completely disappears. The same effects were produced on blood. In both cases the opacity of the liquids prevented microscopic examination. The pure alkaloid is so dear, its preparation being so expensive, that its industrial use cannot be expected; but it deserves the attention of the medical profession, as it may be useful in the treatment of certain diseases.—(*Dingler's Polytech. Jour.*)—*Bul. de la Soc. d'Encour, etc., July, 1886.* C.

MANNER OF RETARDING COMBUSTION.—The *Moniteur Industriel* describes a process, due to M. Ebert, of Dresden, by which the combustion of coal may be retarded, in order to reduce the consumption as far as possible, in certain metallurgic operations. The ore and the coal are pulverized or granulated. To the mixture or to the coal alone is added, before introduction into the furnace, a refractory substance such as soluble glass. This protects it against the action of the flame until the ore has acquired the proper degree of heat. Then the dissolution takes place and the carburetted metal in liquid state is separated from the dross in small drops. The success of the operation is a question of proportion.—*Chron. Industr., Sept. 19, 1886.* C.

CLARIFYING OF OILS BY PERMANGANATE OF POTASH.—The method is generally as follows: After having dissolved one kilogram of small crystals

of permanganate of potash in seven gallons of water (according to Mitscherlich, this product is soluble in fifteen to sixteen parts cold water), to this solution—which is of an intense purple color—thirty kilograms of the oil to be clarified is added little by little. The whole is allowed to stand two days, but is stirred very frequently. At the end of that time, four and one-half gallons of water is added and five kilograms of the hydrochloric acid of commerce, 20° to 22° B., and the whole stirred again. After a few days, the acidulated water is carefully drawn off, the oil is treated with hot water to cleanse it from traces of acid, and is then passed through a charcoal filter. Linseed, poppy, olive, palm and fish-oils can be successfully clarified in this manner. —*Chron. Industr., Sept. 12, 1886.* C.

SUGARS.—Type, $C_6 H_{12} O_6$. (*Schutzenberger's Traité de Chimie, Générale*, **5**. Paris, 1887.—*Phenose*.—Under this name is known an uncrystallizable and deliquescent sugar, which is very soluble in water and in alcohol, insoluble in ether. It was obtained by Carius in fixing upon benzine three molecules of hypochlorous acid,

$$C_6 H_6 + 3 Cl H O = C_6 H_9 O_3 Cl_3,$$

and in treating the chlorinated product thus obtained, with sodium carbonate,

$$C_6 H_9 O_3 Cl_3 + 3 H_2 O = 3 H Cl + C_6 H_{12} O_6.$$

This synthetical sugar does not ferment, but it browns in the presence of alkalies and in the presence of acids and reduces Fehling's liquid. R. L. B.

MILK SUGAR.—*Lactose*, $C_{12} H_{22} O_{11}, H_2 O$. (*Schutzenberger's Traité de Chimie Générale*, **5**. Paris, 1887.)—From a chemical point of view, milk sugar stands midway between grape sugar and cane sugar. Like glucose, it browns in the presence of alkalies, and in alkaline solutions exerts a reducing action upon metallic compounds.

A saturated, aqueous solution of lactose, at 10° C., contains 14·55 for 100 of sugar. Freshly prepared solutions possess a greater dextrogyrous rotary power than do those which have been kept some time. Using a one per cent. solution of glucose, and Fehling's solution as usually prepared, one molecule of anhydrous glucose reduced 5·26 molecules of cupric oxide. Using a solution of milk sugar of the same strength (one part to 100) and Fehling's solution, one molecule of anhydrous lactose, $C_{12} H_{22} O_{11}$, reduces 7·4 molecules of cupric oxide.

Recent experiments by M. G. Bouchardat have proven that this carbohydrate, hitherto supposed to exist only in the milk of the mammalia, is present also in the milky juice of some plants belonging to the Natural Order *Sapotaceæ*.

Milk sugar does not ferment in the presence of brewer's yeast, but certain bacilliary ferments (schizomytes) transform it into alcohol. This reaction explains the possibility of obtaining from milk fermented liquors; such, for example, as the nutritious koumiss, which is prepared from mares' milk by the Tartars, as they roam over the vast steppes of Asia.

NOTE.—If Bouchardat's experiments shall be confirmed, the origin of the intoxicating liquor prepared in Africa from the flowers of certain species of

Bassia, will no longer remain unexplained chemically. A single tree of *Bassia longifolia*, it is stated, will yield from 200 to 400 pounds of flowers collected after they have fallen, and these flowers are largely consumed in the preparation of spiritous liquors. R. L. B.

TARTRAZIN. (W. H. Richardson *Journal Society of Dyers and Colorists*, **3**, 1).—Tartrazin, according to its method of preparation, possesses some resemblance to chrysamine. The commercial article is a sulphonic acid, thus differing from chrysamine. Tartrazin gives, with basic coal-tar colors, a series of well-defined precipitates, which may be regarded as the tartrazinates of the respective color bases.

Elementary tartrazin forms a yellow powder, sparingly soluble in water and alcohol, insoluble in dilute acids, easily soluble in warm concentrated acetic or hydrochloric acids. The acetic acid solution is rendered colorless by zinc powder, and becomes violet on standing in the air. The tartrazinates of the metals are mostly sparingly soluble in water. The barium salt is prepared by adding barium chloride to a solution of tartrazin in ammonia. Rosaniline tartrazinate is best prepared by mixing dilute solutions of commercial tartrazin and magenta, and allowing to stand. The brown flocculent precipitate may be purified from dilute alcohol or boiling water. Dried at 100°, it forms a greenish powder, which behaves as a very stable salt. Wool is dyed a color somewhat yellower than with the ordinary rosaniline salts. H. T.

SOME ALLEGED NEW ELEMENTS.—A. Pringle (*Chem. News*, **54**, 167), claims to have discovered six new substances in some lower silurian rocks in Selkirk. Five are said to be metals, and the other is a substance resembling selenium, and which he calls *hesperisium*. One metal is like iron, but does not give the rhodanate reaction, nor that with tannin. Another resembles lead, is quite fusible and volatile, and forms yellow and green salts; another is black, and he names it *erebodium*; the fourth is a light-gray powder, and the last is dark in color. For three of these elements, the author assigns the equivalents 95·4, 43·6 and 74. W. H. G.

THE EQUIVALENT OF GADOLINIUM OXIDE. By A. Nordenskïold (*Comptes Rendus*, **103**, 795).—Gadolinium oxide is a mixture of the oxides of yttrium, erbium and ytterbium, and was first obtained from the gadolinite found at Ytterby. It is precipitated by ammonium oxalate and also by potassium sulphate, and the three constituents cannot be separated quantitatively. Although this mixture has been separated from a number of different minerals and by different methods, the greatest variation for the mean value of its molecular weight, which is 261·9, is only one per cent., a variation that is within the error of experiment. The curious fact follows that although gadolinium oxide is not the oxide of a simple substance, but a mixture of three isomorphous oxides, it has a constant molecular weight, even when obtained from totally different minerals found in widely separated localities. [See on this point Prof. Crookes' remark, in his address, "Genesis of the Elements."—ED.] W. H. G.

THE ACTION OF ELECTRIC DISCHARGES ON PURE NITROGEN. By J. J. Thomson and R. Threlfall (*Proc. London Royal Soc.* **40**, 329.)—When strong electric discharges are passed through pure nitrogen under a pressure not

more than twenty millimetres, a diminution of volume takes place, and after a time attains a maximum which is greater as the pressure is lower. With a pressure of eight millimetres, the decrease amounts to eight or ten per cent. of the original volume. By long heating to 100°, the gas returns to its original volume. The authors believe that this phenomenon is caused by the formation of an allotropic form of nitrogen.

The same authors have found (*loc. cit.*, 340,) that the most powerful electrical discharges do not occasion the formation of ozone when passed through oxygen placed in a strong electrical field. W. H. G.

THE ATOMIC WEIGHT OF GOLD.—Gerhard Krüss (*Berl. Ber.* **20,** 205,) has determined the atomic weight of gold by the analysis of neutral trichloride and of potassium gold bromide; for a mean value he has found 196·669, the maximum of five methods being 196·741, while the minimum was 196·619. He regards 196·64 as the atomic weight most probably correct.

W. H. G.

GEOLOGY AND MINERALOGY.

CARD TO GEOLOGISTS.—The fourth meeting of the American Committee of the International Congress of Geologists, which has represented the United States in the International Sessions at Paris, Bologna, and Berlin, was held in Albany, on April 6th and 7th. The business it transacted was of unusual importance, and is earnestly commended to the attention of all geologists who may read this notice. At a previous meeting of the committee, sub-committees had been appointed and charged with the duty (each under a separate chairman) of co-operating in the production of a report which should embody the best thoughts of American Geologists on the several subjects into which the geological column was divided. This plan was found to be objectionable on account of the wide dispersion over the United States of the members of the sub-committees, which rendered co-operation difficult. Accordingly, the plan of the English Committee at the last session of the Congress was substituted, which consisted in appointing reporters for each of the subjects, and making them answerable for the preparation of a report. The duty of these reporters will be, not to confine their reports to the presentation of their own views, or those of any given small number of geologists; but to elicit, by personal correspondence, and in every other available manner, the views of all students of these subjects who can be induced to express any; and to resume these views in a paper to be submitted to the Committee and ultimately to the Geological and Geographical Section of the American Association for the Advancement of Science. In this way a fair representation can be made, at the next Congress, of American geological thought. The following is a list of the subjects to be treated and the persons selected to present them, and *all geologists are requested to aid the important national work to be undertaken, by sending to the appropriate reporter, hereby indicated, any suggestions which may occur to him as bearing on his work. Those who neglect this appeal, cannot accuse the American Committee of slighting the views of their countrymen.*

"Quaternary, Recent and Archæology."—Major J. W. Powell, Director United States Geological Survey, Washington, D. C.

"Cainozoic" (Marine).—Prof. E. A. Smith, University of Alabama, Tuscaloosa County, Ala.

"Cainozoic" (Interior).—Prof. E. D. Cope, 2102 Pine Street, Philadelphia.

"Mesozoic."—Prof. Geo. H. Cook, Rutgers College, New Brunswick, N. J.

"Upper Palæozoic."—Prof. J. J. Stevenson, University of the City of New York, (Carbonic); and Prof. H. S. Williams, Cornell University, Ithaca, N. Y., (Devonic).

"Lower Palæozoic."—Prof. N. H. Winchell, University of Minnesota, Minneapolis.

"Archæan."—Dr. Persifor Frazer, 201 South Fifth Street, Philadelphia.

It is the intention of the Committee to hold a meeting next summer at which these reports shall be considered, discussed and amended; and to bring the conclusions arrived at by them before the American Association for the Advancement of Science (or rather Section "E" thereof) at its meeting to be held in New York City on August 10th, thereafter.

The resolution herewith subjoined was adopted by the American Committee:

"That we recommend to American geologists the acceptance of the conclusions of the International Congress of Geologists; but that we will be prepared to advocate certain changes in the details in case these questions are ever re-opened in the International Congress; said changes to be formulated at a subsequent meeting of the Committee, it being understood that the Committee will present such additions as are deemed necessary by American geologists to the Congress of London, of 1888."

PERSIFOR FRAZER (*Secretary American Committee*).

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April 20, 1887.*]

HALL OF THE INSTITUTE, April 20, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, 136 members and sixteen visitors.

Additions to membership since last meeting, six.

The Special Committees on State Weather Service and on PAUL LA COUR'S protest, reported progress and were continued.

A letter was read from Mr. JOHN J. HOLTZAPFEL, of London, accepting election as a corresponding member.

Sergeant T. F. TOWNSEND, of the United States Signal Service, read a paper "On the Use of Oil for Stilling Waves," with a description of a new Oil Distributor for the Use of Mariners. Referred for publication.

MR. ALEX. E. OUTERBRIDGE, JR., of Philadelphia, described a new Method of obtaining Castings from Carbonized Fabrics, and exhibited numerous specimens of castings in iron obtained in this manner.

Final action was taken on certain Amendments to the By-Laws. Adjourned.

WM. H. WAHL, *Secretary*.

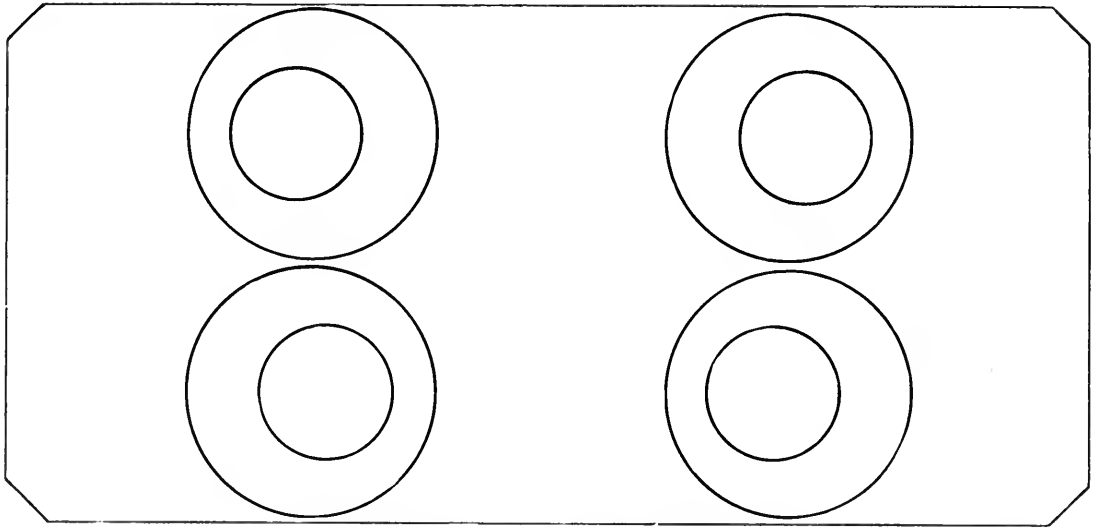
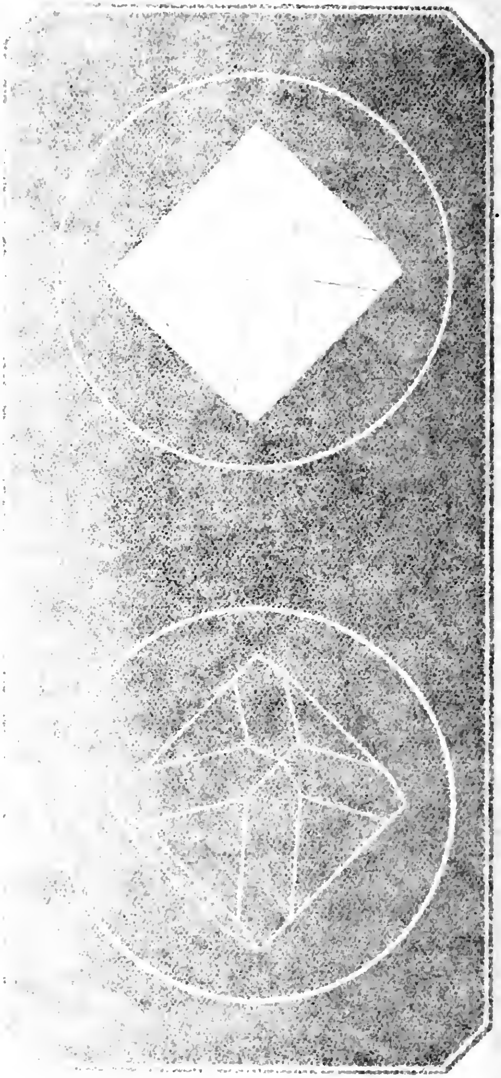


Fig. 9.—Phenomenon of Horizontal Moon.—Reute.



JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXIII. JUNE, 1887. No. 6.

THE STEREOSCOPE AND ITS APPLICATIONS.

BY PROF. CHAS. F. HIMES, Ph.D.

(*Concluded from vol. cxxiii, page 408.*)

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 14, 1887.*]

A very simple form of instrument, and one of great convenience, which leaves the hands perfectly free, and which anyone can adopt to his own interocular distance, is that of spectacles, with stereoscopic semi-lenses; or, as I have found equally effective, ordinary spectacles of about six inches focus, simply widened by inserting a piece in the bridge, so that the eyes may look through the margins of the lenses instead of through the centres. But it may be asked if the instrument does so much, what becomes of the criterion of muscular effort in the movement of the axes? We will see that there is still residual work of this kind to be accomplished, because of the impossibility of the exact superposition of dissimilar pictures. Let us see, therefore, in what this dissimilarity consists, and how it may be best stated for our purposes. Let us take as a very simple subject, the screen of vertical lines as our background

for convenience of reference, and the rod with an arrow of black card-board several feet in front of it.

Upon looking at it first with one eye open and then with the other eye open, while the head is kept in a fixed position, it will be noticed that the projection of the arrow referred to the same line on the screen, will be further to the left when looked at by the right eye than when looked at by the left eye. Or we can say that in right-eye pictures objects in the foreground are further to left of the same object in the background compared with the left-eye picture. So in the diagram (*Fig. 9*) the upper pair of diagrams would represent right- and left-eye drawings of a concave frustum of a cone, because the centre of the smaller base in one case is further to the right, and in the other further to the left compared with the centres of the larger bases, while the lower pair of diagrams, for similar reasons, represents a convex frustum. This rule applies, of course, to the most complicated subject, and would enable any one to assort unmounted photographic stereographs, as has often been my own practice. But it will answer our purpose better to describe the completed stereograph,—the pair of pictures mounted properly upon a card. In this case, we see at once that similar points in the foreground will be nearer together than similar points in the background. Thus, we might say that in the stereoscopic diagram of the convex frustum of the cone the centres of the smaller circles are nearer together than those of the larger circles. Thus, as we measure with a pair of compasses, the distances between the similar points of a more complicated stereograph, passing from objects in the immediate foreground, there will be a gradual slight, but very perceptible, increase in the distance.

Now, to return to our simple diagram (*Fig. 2*), and regard both sides of it. Two of the squares will be seen to be nearer together, and in the stereoscope binocular combination will take place, and that difference assert itself by invariable, uncontrollable, persistent location of that square in front of the other. This rule, which serves to test the correctness of the mounting of the pictures of a stereograph, serves just as well to answer a very natural query that arises here, as to the effect of incorrect mounting,—of transposition of the pictures, thus presenting the left eye the right-eye picture, and at the same time the right eye the left-eye picture. This

would simply reverse the order of the distances between similar points. Objects in the foreground would now be further apart than objects in the background. The binocular combination of these by means of the stereoscope, by its inexorable method, would reverse the natural distances of the objects from the eye. Objects in the background would be brought to the front, and those in the foreground be caused to recede into the distance. Forms would be inverted. Elevations would be converted into depressions, and depressions into elevations, relief into intaglio. This false effect, called pseudoscopic effect, to distinguish it from the ordinary stereoscopic effect, is one of the most interesting facts, and one most strongly corroborative of the theory of the stereoscope. It also opens up a fruitful field for experiment and investigation, sometimes disappointing us, but oftener affording remarkable surprises in spite of all ground for anticipation. In *Fig. 9* you will readily notice that the transposition of the diagrams of either pair will producê the other, with the reversed stereoscopic effect. So the most complicated photographic stereographs, with every variety of object, and all their wealth of detail—landscapes, interiors, statuary, apparatus—if cut apart and transposed, should manifest a similar effect. The ordinary stereographs in the market answer very well for experiments. But all will not be found to respond to our statement. In many cases, especially when persons have not been apprised of the change, and are unaccustomed to critical use of the instrument, the stereoscopic effect will apparently persist, not as strikingly, perhaps, there may be an expression of dissatisfaction on the part of the observer in comparison with some other stereographs, accompanied, it may be, with the statement, that it appears better with one eye than with both, but the trees in front of the cottage refuse to recede behind it, the portico will not move to the rear, and the sloping lawn in front not slope to the rear, at an opposite angle, as they all should. Neither will a face appear as a mask. This results simply from the struggle between what is usual and natural and anticipated and what is unusual or unnatural, and often even impossible; between the single binocular criterion and the cumulative effect of all the monocular criteria of distance and form. Thus, that the trees should recede beyond the cottage, implies not only a violation of ordinary perspective, but an unnatural appearance of transparency in the cottage. But often after prolonged examination, the

absolute character of the binocular criterion, its entire independence of the conditions of ordinary perspective, manifests itself, first in a recognized persistence in the disposition of some object in the background to start to the front, as binocular perspective overbears all ordinary perspective.

At first it may be such objects as do least violence to our preconceived notions of position, and finally all will come into the most unnatural positions as demanded. But this control over us of what is usual in appearance, which we found applied to the objects themselves, when viewed with one eye, as in the mould which I exhibited, which appeared to be a relief, applies, in many cases, even to the stereographs of the objects. The stereograph of the mould, even to experts, does not, at first, manifest its true character, and, of course, it would be expecting too much that the transposed stereograph of the medallion should apnear as a mould. But frequently when difficulty has been experienced by individuals in obtaining pseudoscopic effect, I have succeeded in causing it to appear at once by placing the familiar object in an unusual position. By simply turning the pseudograph, as we may call it, upside down in the stereoscope, its true character will often appear. Thus the stereograph of the mould upside down occasions no difficulty, and then, generally, when placed in its proper position, it retains its character as a mould. So, too, the mould photographed in a horizontal position I find is more likely to maintain its character in the stereoscope. Again, by taking advantage of accidental features, for example, the tacks by which it is fixed to the support or the knot on a cord, these readily assume their proper positions, and, insignificant as they are, drag the whole picture into proper relief. Nothing exhibits more clearly, than such facts as these, the effect of the most minute conditions in stereoscopic vision. In the photograph upon the screen, a combination has been made upon a table of objects of wood, metal, and glass, some with peculiar lustre, of familiar and unfamiliar forms and sizes, and without marked background. It forms a beautiful stereograph. But, when mounted pseudoscopically, at first it is very unsatisfactory, persons sometimes stop and wipe the glasses of the stereoscope, but finally, as a rule, the objects arrange themselves in inverse order, suspended in mid-air, on a plane with the reversed slope of the table. The effect is magical. When great difficulty is experienced in obtaining it, simple inversion of the pseudograph will produce it, and it

will be retained after it has been properly placed. The photograph of the old jelly mould on the screen is an excellent subject that yields its proper effect at once. It is a suggestion taken from Dr. Carpenter. There is little familiar about it.

Now, the differences between the binocular pictures, minute as they must necessarily be, would entirely escape representation in any ordinary drawing, and in a subject of any complexity, even with the greatest care could not be rendered, might even be reversed in character. The infinitesimal character of the differences between the binocular pictures, which the eyes can take hold of and translate into distance and form, can hardly be appreciated from mere statement. If a slip, about 2¾ x 2¾ inches, is printed from ordinary type, and the type are then distributed and reset, as nearly as possible in the same way, an impression from the latter combined in the stereoscope with one from the former, will manifest differences in the projection of some letters in front of the plane of the paper, and the recession of others behind it, or even of words inclined at different angles to the plane of the paper—effects due to varying distances between the similar letters. It has been proposed to test bank notes in this way. If similar halves from the same plate are combined in the stereoscope, they will remain flat, whilst if halves from different plates are combined, the minutest differences will manifest themselves, as in the printed slips alluded to. So the celebrated Chimenti pictures in the Museum at Lille, which Sir David Brewster regarded as stereoscopic mates, on close examination only exhibit such differences as might be expected between any original and its copy, as they give mixed pseudoscopic and stereoscopic effect.

But just at this point, photography comes to our aid, rendering, with mathematical accuracy, minutest differences. All that would be necessary, would be to take two pictures from points of view about three inches apart, either with the same camera in succession, or with two cameras simultaneously; or, with what is practically the same, the so-called stereoscopic camera, in which case, the two pictures are on halves of the same plate of glass. One advantage of the double camera is, that moving objects are included in its range. But when the negatives are on the same piece of glass, the paper prints made from them must be cut apart, and transposed in mounting for the stereoscope. This has puzzled

many, for is not the right-eye picture on the right half of the glass, and the left-eye on the left half? Even Sir David Brewster* seems to reason somewhat in this way in his description of what he calls a camera stereoscope, which he recommends very highly. He says, that by combining the two pictures on the ground glass of a binocular camera, by means of a lenticular stereoscope attached to the back of it, groups of figures, and so forth, may be seen in relief—upside down, to be sure, but in relief. It is not easy to test this statement with the ordinary stereoscopic camera, because the lenses are more than the interocular distance apart, and the similar points of the ground glass pictures are too far apart, but by cutting a strip out of the centre of the negative taken with one of these cameras, as I have done, and thus bringing the similar points within two and three-fourth inches of each other, and then supporting the halves on a piece of plain glass, just as they present themselves to the eye on the ground glass, and introducing them into the stereoscope, the same effect should be produced. It will be found to be pseudoscopic. If the subject has been carefully selected, unmistakably so; if a landscape, or a portrait, the difficulty before alluded to, in obtaining it, will be experienced. As this fact has a bearing on other interesting applications of the stereoscopic principle, we may take more time to make it apparent. Let us test it by our simple rule, that similar points of the pictures nearer together will appear nearer the observer. Any change in the position of the pictures that does not affect this condition will not affect their binocular character. Now, what is the character of the picture on the ground glass. First, let us note what presentations of a transparent picture can be made. On the screen will be recognized a negative of our screen of vertical lines and arrow. The letters have been introduced to indicate changes. First then we have the normal position, next simply turned upside down, next in an upright position, but as if seen from the other side, or looking upon the face of type—say type-inverted, and lastly, both upside down and type-inverted. Now, the image of an object thrown by a lens appears upside down and type-inverted to an observer upon the same side of the screen as the lens, or as it would appear to you if the lantern were projecting images from objects in their natural position, *Fig.*

* *The Stereoscope*, p. 126.

6, a, but if these same images upon the screen were looked at from the other side of the screen, they would still be upside down, but the type-inversion would be corrected; they would only be upside down, like a negative, upside down and with the film side from you. which, by simply turning right side up, becomes normal, *Fig. 6, b,* Now, the two pictures thrown upon the ground glass of the binocular camera have the same character; seen from behind on the ground glass, they are simply upside down. (By means of transparent screens carrying enlarged right- and left-eye pictures, the lecturer illustrated this point fully.) Thus we see that by taking two stereoscopic pictures, which are properly placed, and turning

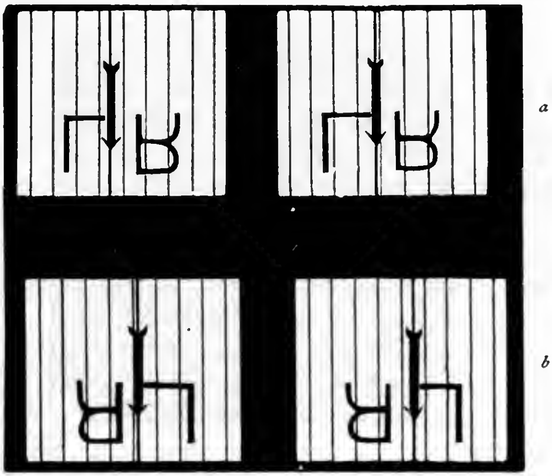

Fig. 6.

each for itself upside down, we can change the relation between the distances of similar points in the pictures; those that were nearer together before will now be further apart—the combination will be pseudoscopic. If it is a glass stereograph, and we fasten the pictures in their new positions, no turning of the whole combination, no mode of looking at it from front or rear, can change this condition—it is pseudoscopic and will remain so until each picture is inverted for itself, or until they are separated and transposed, which would bring the same edges of the halves together as separate inversion would. Thus the pictures on the ground glass of the stereoscopic camera are simply upside down, *Fig. 6, b;* if each could be turned right side up for itself the combination would be

stereoscopic; unless that is done, the combination must be pseudoscopic. The images upon the ground glass can not be inverted, but a perfectly equivalent experiment can readily be made with a glass negative. But let us notice the effect of the width of the lens upon the picture produced by it. Each part of the lens contributes to the picture. Now, I placed in front of an ordinary one-fourth size portrait lens, about one and one-half inches in diameter a stop with an aperture three-sixteenths of an inch in diameter at *a* (*Fig.* 7), with its centre three-eighths of an inch from the centre of the stop and took a negative; then took a negative with a stop with an aperture at *a*, of same size and at the same distance from the centre, and then took a negative with a central aperture *c*, of the

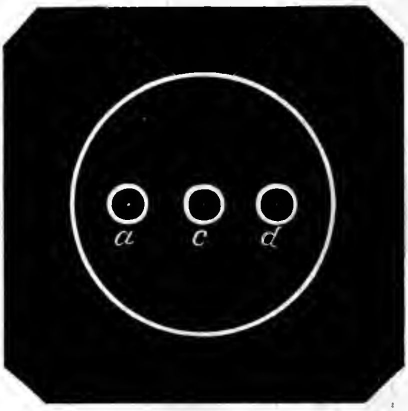

Fig. 7.

same size. These negatives, now thrown upon the screen, manifest unmistakably the same differences that would be expected in pictures taken by lenses separated the same distance from each other. Prints from any two of them combined in the stereoscope give an effect as decided as any ordinary stereograph. Even the combination of the picture by the central aperture with one by a lateral aperture is very decided. It is plain, then, that when the full aperture of the lens is used, the resulting picture must be a fusion of many dissimilar pictures, and, in so far, must be wanting in precision. This will be true, of course, to the greatest extent of objects in the immediate foreground. Want of sharpness in cases of near objects is doubtless often attributed to other optical conditions, especially as a diaphragm in front of the lens is a remedy

for this unsuspected cause of defect, as well as for many others. Sir David Brewster was so impressed with this defect of photographic lenses, that he suggested a simple pin-hole camera as the ideal camera, when photographic processes should have become sensitive enough; and as we appear to have reached unlimited photographic sensitiveness, Capt. Colston,* of Paris, has recently given us an illustrated brochure upon the pin-hole camera. Experiments with such a camera some years ago, with wet plates, developed defects that deprive it of an ideal character. But to return to the stereographs by the lens. The subject was selected to bring out this fact. The object, pencils, pens, etc., ranged in distance from the camera only from twenty to twenty-nine inches, and their maximum lateral distance from each other was nine inches. Now, what is true of the pictures by different parts of one-fourth size lens, must be equally true of the pictures by different portions of any lens, however small, even of a microscopic objective, if the object is correspondingly small. If, therefore, a photo-micrograph be taken with one-half of an objective, and then one with the other half of the objective, these two combined in the stereoscope should give an appearance of relief that the microscope itself could not give, free from errors of interpretation, as to distance and form. And so they will. I have here a stereo-micrograph of sun-stone, in which the crystals are located by the stereoscope, and the section shows depth, and all the qualities of the ordinary stereograph. It was taken many years ago by Prof. O. N. Rood, now of Columbia College, and the method published,† and it is a matter of surprise that in these days of photo-micrography, no one has cultivated this branch, or indeed that micro-stereographs of many objects are not in the market. I would just say that the method suggested, although giving results as stated, was abandoned by Prof. Rood for another, principally on account of difficulties in illumination. But we are not restricted to photo-micrographs in the application of the stereoscopic principle. As might have been anticipated, soon after the realization of the great superiority of vision with two eyes over monocular vision, attempts were made to apply the principle in microscopic vision. The difference between

* *La Photographie sous Objectif.* Paris, 1887.

† *American Journal of Science*, vol. xxxii, p. 192. 1861.

the views of an object by the different halves of the objective was recognized, and the possibility suggested of presenting one to one eye and the other to the other eye, and thus obtaining microscopic vision in relief. Prof. Riddell, of New Orleans, seems first to have devised a binocular microscope in 1851; but in his first instrument the right eye looked through the right half of the lens, and the result was not stereoscopic, but pseudoscopic. In describing the appearance in it he likens a metal spherule to a glass ball silvered on the underside, and a crystal of galena to an empty box.*

You might have inferred as much from the full discussion we have had, with this application in view, of the so-called camera stereoscope of Sir David Brewster. The pictures through the halves of the lens, as they are inverted, are similar in binocular

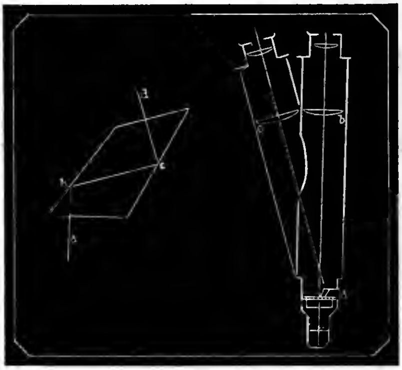

FIG. 8.

character to those of the ground glass of the stereoscopic camera, and to produce stereoscopic effect, it is necessary that they should be transposed; that the right eye should look through the left half of lens, and the left eye through the right half. Many optical contrivances have been devised to meet this requirement, but that of Mr. Wenham has done so much by its extreme simplicity and cheapness, as well as effectiveness, to render the binocular microscope a possibility for all, and that, too, without loss of its monocular character, that it will serve best for illustration. In the diagram (*Fig. 8.*) it will be noticed, that the ray to the right eye passes directly through the left half of the lens, whilst the ray through the right half of the lens is deviated across the original path into the

* *American Journal of Science*, vol. xv. 1853.

left eye, by means of a peculiar prism placed above the objective. In the larger diagram of the prism the ray may be followed, entering perpendicular to the lower surface, then totally reflected and again totally reflected, and emerging finally from the prism at right angles to its surface, consequently without refraction, in such direction as to enter the left-eye tube of the binocular body.

By sliding this prism out, the instrument can at once be converted into a monocular, and again be as readily converted into a binocular, thus affording apportunity for comparison of the two effects. Two *à priori* objections prove in practice groundless. First, the image formed by rays passing through the prism, as they traverse a longer path, will be larger, and, by reason of reflections and imperfections of the glass, less distinct than the other. But it can easily be demonstrated by the stereoscope that slight differences in size can be overcome by the eyes, and that even a faint or imperfect picture can contribute a great deal when combined stereoscopically with a perfect one. The advantages of a binocular microscope, in cases where applicable, cannot be overestimated. The comfort in the conjoint use of both eyes, especially to those unaccustomed to the use of the microscope, is great; even a non-stereoscopic binocular, in which portions of light from the whole lens pass into each eye, adds much to comfort in use. But this question as to whether there is any advantage in a binocular microscope is so often asked, that I will simply give the opinion of Dr. Carpenter upon the point. He says, that in no way could he as certainly or as vividly image the form to himself, or be as conscious of saving fatigue. That this is not attributable merely, perhaps not so much to the conjoint use of the two eyes, as to absence of mental effort required for the interpretation of the microscopic pictures, when the solid form has to be ideally constructed from it, chiefly by means of information obtained by focal adjustment, instead of being presented directly to the mind's eye. Not all writers on this subject are equally clear. Hogg says, that the great disadvantages of the earlier forms of binocular microscopes was, that to most persons the view given was pseudoscopic, when in the nature of the case, as we have seen as far as there was any effect, it should have been pseudoscopic to every one; some might have overlooked it, or been controlled by other conditions, but in no case could true stereoscopic effect be produced. Even so

high an authority as Helmholtz* accompanies the statement, that the stereoscopic effect is very surprising and facilitates wonderfully the observation of complicated forms, with another, that it occurs by reason of entirely different conditions than in other stereoscopic instruments. That we have here no pictures of an object taken from different points of view, for one objective of the microscope furnishes both pictures for both eyes, and only half of the light is assigned to one eye, and the other half to the other eye. His elaborate explanation of the effect involves the formation of confusion circles by points out of focus. Now, whilst vision with the binocular microscope is abnormal, and modified by many conditions, when we recall the photographic pictures furnished by different halves of the one-fourth size photographic lens, and their perfect stereoscopic character, we cannot exclude the same condition present in the use of the binocular microscope, from the principal share in the production of the effect.

But we have employed the term convergence of the optic axis in such a way, that the impression may have been created that such convergence is necessary for stereoscopic effect. This was, indeed, almost a controlling view with the early investigators of the subject. Now, whilst there is necessarily always convergence of the axes, to some degree, in normal vision, I was convinced, many years ago, upon investigation, of the non-essential or secondary character of this condition in production of stereoscopic effect,† and the subject has more recently been independently, most exhaustively discussed by Prof. LeConte Stevens.‡

It may be regarded as accepted, that convergence is not necessary. Experiments may easily be made by anyone upon that interesting point by means of ordinary stereographs. By looking at a distant object, not too intently, and introducing before the eyes, at about the limit of distinct vision, an ordinary stereograph, after some practice, the habit of accommodation and convergence will be overcome. Four pictures may at first appear, but gradually the interior ones will approach each other, and finally coalesce, with

* *Physiologische Optik*, p. 682.

† *American Journal of Photography*, September 1, 1862. *Proceedings of New York Academy of Sciences*, February 13, 1882.

‡ *American Journal of Science*, vol. xxii, p. 358. 1881.

resulting stereoscopic effect. In this case, controlled by the convergency theory, it was regarded as an essential condition of success by Brewster, Rogers, LeConte, Tyndall, and others, that the distance between similar points of the two pictures should not exceed the interocular distance, say two and three-fourths inches. If by practice, however, anyone should acquire facility in thus combining the pictures of the ordinary stereograph, it will be found that, by cutting them apart, and gradually sliding the halves further apart, combination can be effected when the distance exceeds three inches, or even four inches in my own case, and with complete stereoscopic effect, although, in such cases, the axes must be divergent. Still, in this case, there remains the necessity for movement of the optic axes, as they pass from points nearer together to other similar points further apart, a movement associated with normal perception of distance and form. But this perception of stereoscopic effect, whilst the optic axes are divergent, is far more common than might be supposed. In many, perhaps most, cases, in using a stereoscope there is this divergence. In many of the stereographs in the market, the distance between similar points greatly exceeds the average interocular distance, and the prisms do not produce superposition. Prof. LeConte Stevens, by comparing the foreground interval of a large number of stereographs with the deviating power of thirty different pairs of lenticular prisms, employed in the ordinary stereoscope, determined, that, for the average interocular distance, axial divergence is frequent in the use of the stereoscope.* Just at this point, we must admit that, whilst play of the optic axes is important in our study of the form of objects, there are facts that indicate that binocular perception of distance may take place, when such movement cannot accompany it. Prof. Dove first tested this, by illuminating the stereograph by an electric spark, an experiment since repeated by many, with production of unmistakable stereoscopic effect. So also an object illuminated by a flash of lightning exhibits relief. We cannot conceive of movement of the optic axes occurring in such brief intervals. The position of the pictures on the retinæ must therefore give us a criterion, not the sole one, but an important one. The theory of corresponding retinal points seems to meet the case. Stated briefly, the internal

* *American Journal of Science*, vol. xxii, p. 444.

or nasal half of one retina corresponds to the external or temporal half of the other retina. Points are seen single when their images fall on corresponding points, the images of points nearer or more remote will not then fall upon corresponding points, and they will be seen double, although we may not be conscious of the fact, and most persons may have difficulty in verifying the statement. It is this doubling of images of points nearer or more remote than those observed, and the difference in character between those nearer and more remote, that accompanies all normal vision, that unconsciously aids, at least, in our perception of distance.

Now, a few hasty suggestions as to some other applications of the stereoscope. When first introduced, its range of application seemed very restricted; even when it was widened in the number and character of its subjects by photography, it seemed restricted to objects of ordinary unaided vision. We have seen how not only the principle was soon made directly applicable to the microscope, but magnified stereographs were demonstrated possibilities. Application to extra-terrestrial objects was not anticipated. But about the same time, Rutherford and De La Rue discovered that they had stereographs of the moon. I do not know that they intentionally took the photographs with this in view. They had not taken their photographs from points far enough apart to give binocular parallax. But, if I wished to obtain a stereograph of a bust, I could either move my camera three inches to the right or to the left, or what would produce the same effect, rotate the bust on a vertical axis through a small angle, so as to bring a little more of one side into view, and take a picture. This plan, by tilting the stage of the microscope for stereographs of minute objects has already been alluded to. Now, it is true, as a general statement, that the moon always presents the same side to our view by reason of the identity of the time of its rotation on its axis and of revolution in its orbit. But it is not rigidly correct. The rate of motion varies slightly in different portions of the orbit, causing so-called libration in longitude, by reason of which a little more of one side is exposed to our view. The moon turns around just enough to afford us stereoscopic photographs at these times, which give the most surprising, in fact exaggerated, effect. Wonderful as these are, I was unable to obtain in the market those by Rutherford at all, although advertised for sale, but found some by De La

Rue. They manifest not only the form of the moon, but exhibit almost a pitted appearance, mountain ranges and solitary peaks stand out in bold relief. So, too, De La Rue has obtained stereographs of the sun. Between these two wide limits, the microscopic and the telescopic, lie all varieties of subjects and numberless questions, which the stereoscope can aid in investigating. The so-called "Phenomenon of the Horizontal Moon" has been discussed since the days of Ptolemy. The illusion of size depends on the illusion of distance. Sir David Brewster and Prof. Reute devised stereoscopic illustrations of this connection. That of Prof. Reute, on the screen, *Fig. 9*, will be recognized as diagrams of convex and concave conical frusta, the smaller circles in each case being of the same size, but in the stereoscope, as they are made to assume positions of bases of the frusta, the one more remote appears larger.

From several diagrams of my own on this point, I select one of some theoretical interest. In it a single small circle is represented in the right hand diagram by two equal circles at different distances (*Fig. 10*). Impressed with the necessary rapidity of movement of the optic axes in ordinary vision, my expectation was that the alternate combination of this circle, in succession, with the equal circles of the other diagram, would be so rapid, that the results could be compared, and the same circle be made to appear larger and smaller in succession. To my surprise, both frusta, the convex and concave, presented themselves at the same time, the same circle seemed to occupy two places at the same time, and with apparent size corresponding to the distance The natural explanation was that it was an illustration of the rapidity of the movement of the optic axes, and our unconsciousness of it. But unfortunately for this view, Prof. Le Conte Stevens* has called attention to the fact, since verified by myself, that it manifests the same character when illuminated by an electric spark. Again, there are phenomena which we cannot locate in space by direct observation, for want of time, and a single photograph assists us but little in their study. The photograph of a moving object, as a ball, only gives us the projection of its path, a stereograph would locate its path in space for us. To vary the application, the photo-

* *American Journal of Science*, vol. xxvi, Oct., 1882.

graph of the electric sparks upon the screen (*Fig. 11*) exhibits a confused mass of interlacing lines. But by combining this with the stereoscopic mate, taken at the same time, this tangle of lines assumes form as the path of each spark locates itself in space. Application of this method to the photographic study of the discharges of atmospheric electricity might add to the value of such photographs. On the other hand, in the study of the forms of clouds, simultaneous photographs of them, from points widely separated, might give invaluable information. But there are ordinary subjects which photographs with all their accuracy are utterly inadequate to render, of which they give us limited and perhaps illusory information. Impressed with this fact, a few years ago, when about to make a photographic study of the glacier system around the Matterhorn, I decided unhesitatingly upon a

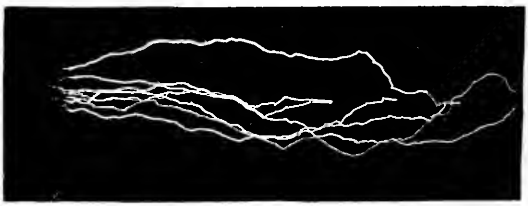

FIG. 11.

stereoscopic outfit in spite of the extreme desirability of reducing impedimenta, where mule and man transportation alone were available. A few of the finest of these, as lantern-slides upon the screen, are almost meaningless; no explanatory statements can give them full value; even these with the bold peaks and their cloud banners only reveal their exquisite beauty and wealth of detail, as any one may see, in the stereographs. But photography is not only not always essential, but not available in some most interesting investigations. Besides outline drawings and diagrams of all kinds, what has not yet been fabricated, can be drawn, the camera can be anticipated; ideal apparatus, forms suggestive or tentative, can be rendered stereoscopic, and representations of phenomena almost a substitute for the reality can be produced. A simple little piece of apparatus, devised by Prof. Rood,* renders this extremely easy.

* *American Journal of Science*, vol. xxxi, p. 71.

One of the most practical applications is in crystallographic representations. The relations of the several forms of crystals so expensively exhibited by hollow glass models with threads for axes, can be as completely illustrated by the most inexpensive stereographic drawings of every variety. Sets of stereographs of crystal forms are in the market, and books of instruction in drawing.* But there is still another quality besides form. In the diagram on the screen (*Fig. 12*), devised to investigate comparative brilliancy of objects seen by one and by both eyes, any one, upon observing it in the stereoscope, will be surprised by the appearance of lustre on the arms, where black and white are combined. The stereoscope has been employed by Prof. Dove to investigate the theory of lustre. Applying this fact to crystal models, as in diagram (*Fig. 13*), we get the additional complete reproduction of lustre, almost as of polished

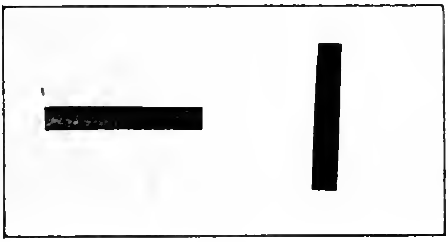

FIG. 12.

glass, as well as of form of the crystals. But we must stop, we have already far exceeded the time proposed to ourselves at the outset, and we will be glad if we have in any way contributed to a reinstatement in favor of a little instrument, which has within itself so many possibilities of instruction and pleasure.

* *Die Elemente der Krystallographie mit Stereoskopischer Darstellung der Krystallformen.*—J. Martius-Matzdorff, Braunschweig. 1871.

TANNIN: ITS PRESENT AND FUTURE SOURCES.

By PROF. HENRY TRIMBLE, of Philadelphia.

[*A Lecture delivered at the* FRANKLIN INSTITUTE, *February 14, 1887.*]

PROF. TRIMBLE was introduced by PROF. PERSIFOR FRAZER, and spoke as follows:

Tannin is a colorless, shining, amorphous, astringent body found in many plants.

It varies according to the source from which it is obtained, but all varieties appear to have the common property of forming a dark blue, or dark green color with ferric salts, giving precipitates with gelatin, and converting animal membrane into insoluble and imputrescible material called leather.

The use of tannin for converting hide into leather was well known to the ancients, but the separation of the principle as a distinct substance was not accomplished until 1793, by Deyeux. This compound, known as tannic acid, when in the pure state, is prepared from galls when the pure acid is desired; this source giving it the name of gallotannic acid, to indicate its origin, and at the same time distinguish it from numerous other tannins from other sources. This gallotannic acid has been fairly well studied, and the opinions of chemists regarding it are much more in harmony than they are in reference to the numerous compounds under the general name of tannin. We will first consider the present sources of tannin which yield us the pure acid.

Galls are the most valuable and important of all tannin materials.

The oldest and best known variety being the oak gall, which results from the sting of an insect called *cynips* in the tender bark of the young shoots of *Quercus lusitanica*, variety *infectoria*, a small shrub three to four feet in height, indigenous to the eastern part of the Mediterranean basin.

The puncture causes the juices of the plant to collect around the eggs; and the resulting galls should be collected before the insect matures sufficiently to pierce the coating and escape, for after that time the amount of tannin is very much lessened. Galls at this

stage of maturity are nearly globular, about three fourths of an inch in diameter, and of a blackish gray color. Those of a white color have been collected after the insect has escaped, and are consequently of inferior quality. The best galls come only from warm countries, those found in this country only yielding thirty to forty per cent. of tannin, while good Aleppo galls (the best commercial variety) yield from sixty to eighty per cent. tannin.

The *Chinese* variety of galls, found on the leaves of *Rhus semialata* were not a regular article of commerce until 1844.

They are very light, hollow, distorted by numerous protuberances, and completely covered by a thick velvety gray down. These galls are much used for the preparation of tannin, of which they yield from seventy to eighty per cent.

Tamarisk galls are obtained from *Tamarix orientalis*, growing in India and northern Africa. They are said to yield fifty per cent. of the purest tannin, and to impart to leather the best color and texture of any tanning material.

Barks.—Much attention has been given by our Government to the development of tannin-yielding materials, by carefully determining the percentage of this constituent in the most promising plants.

Mr. Sargent, in his *Report on the Forests of North America*, says: "The amount of tannin contained in the bark of various trees of the United States has been determined. These determinations give the percentage of tannin; they do not indicate the real value of the bark of the species for tanning, which can only be determined by actual experiment made on a large scale, other properties in the bark, beside the percentage of tannin, affecting the value of the leather prepared with it. These determinations must therefore be regarded as approximations, which will serve in some cases to indicate species not now in general use for this purpose, which may be looked to as possible sources of tannin supply."

Quercus tinctoria, or quercitron oak, is largely used in tanning, giving a reddish fawn-colored leather, and depositing a fine bloom. It contains 5·90 per cent. of tannin and yields no gallic acid. The tree flourishes in the Northern and Middle States.

Quercus prinus, chestnut oak, yields a bark rich in tannin to the extent of 6·25 per cent., and is largely used in preference to all other white oaks in the Northern States.

Quercus falcata, Spanish or red oak, gives 8·59 per cent. tannin, and grows in the eastern United States from New York south to Florida.

Quercus densiflora, tan-bark oak, grows west of the Rocky Mountains, and yields a bark containing 16·46 per cent. of tannin, which fact has made it the most popular of all tanning materials on the Pacific Coast.

In Europe, the bark of the *Quercus robur* and *pedunculata*, which grow there, are used more than all other tanning agents, but in this country there is a bark which, on account of its abundance, exceeds all others in importance in the tanning industry, namely, the *Tsuga canadensis* or *Abies canadensis*, popularly known as hemlock bark. Varieties of this tree grow abundantly in the northern United States and Canada, and the bark yields, according to the variety and locality, from 13·11 to 15·72 per cent. of tannin. So great is the value of this material, that not only is it used in enormous quantities in this country, but it is largely exported. In order to reduce the cost of transportation and at the same time furnish a more available form of this bark, it is exhausted with water and evaporated to a thick or solid extract. This is accomplished by heating in closed copper boilers the ground or chipped bark with successive portions of water until exhausted, running the resulting liquid into a large copper vacuum pan and evaporating in vacuo to the desired consistence when it is run while warm into barrels or boxes for shipment.

The annual production is not far from 15,000 tons. This extract, containing from twenty to twenty-five per cent. of tannin, is one of the cheapest sources of this important material, and the use of it is undoubtedly on the increase; not only for tanning, but very largely also for dyeing purposes, where it forms an important adjunct to many of the more expensive extracts. It is well known that oak-tanned leather is superior in texture and color to that tanned with hemlock, nevertheless, the demand for the latter steadily increases, both here and abroad.

According to the last census report, the annual production of hemlock was 1,101,526 tons, and of oak bark, 353,245 tons. So great is the consumption, that the apparently inexhaustible forests of this wood are rapidly and surely disappearing; not alone on account of the bark, but also on account of the wood, although in

many places the trees are felled, stripped of their bark, and allowed to rot. In Warren County, Pa., 5,000 acres were cut in 1880 for the bark.

Picea Engelmanni, white spruce, on account of the large amount of tannin in the bark—20·56 per cent.—has been employed for tanning in Utah. The barks of some other species of spruce are likewise very astringent.

Castanea vesca, chestnut; both bark and wood are made into an extract. Such an extract is also largely made in France, and some of it occasionally finds its way to this country. A sample which came into my possession, said to represent a large lot, was heavily adulterated with molasses, which goes to show that it is the determination of the cultivators of the beet root to find an outlet for their products. Chestnut extract is largely used in dyeing, where it is valuable not only as a mordant, but also on account of the clear black which it gives.

Rhizophora mangle, mangrove, is a tree indigenous to all tropical countries, on the banks of rivers and in marshy places. On account of the rapidity and luxuriance of its growth, this tree may become an important source of tannin, which exists in the bark of the root to the extent of twenty to thirty per cent. The great objection to it is that it gives a bad color to leather, which must be corrected by the use of other more expensive astringents.

Acacia decurrens, mimosa, a handsome tree, eighty feet in height, indigenous to Australia and Tasmania, yields a bark very rich in tannin, said to reach as high as forty-two per cent. This material, and an extract of it, has been much used in England, and efforts have been made to encourage the cultivation of this and allied species in the colonies. In five years, the tree will yield a large quantity of bark. It has been suggested to introduce it in this country, and when our supplies from oak, hemlock and chestnut are exhausted, it may become a necessity, but not until then can we look for any artificial sources.

Quebracho (*Loxopterygium Lorentzii*), indigenous to Argentine Republic, yields a bark and wood containing twenty per cent. of tannin. The wood is very hard and is, therefore, to a great extent put in the form of an extract before using in the French markets, where it is very popular. It is claimed for some of these extracts that they contain seventy to seventy-five per cent. of tannin. In

all the above barks, it has been found that the proper time for collection is in the spring, when the sap is flowing. The bark is easily stripped off, and is much richer in tannin than that collected late in the season. It is also well known that trees growing on a limestone soil do not yield as much tannin as those growing on other ground.

Fruits.—Dividivi (*Cæsalpinia Coriaria*), the seed pods of a tree, twenty to thirty feet in height, indigenous to West Indies, Mexico, Venezuela, and north Brazil. The pod dries in the form of the letter S, and contains from thirty to fifty per cent. of a valuable tannin which, however, is depreciated by the other constituents which cause rapid fermentation. On this account, the leather tanned with dividivi is soft, rapidly becomes discolored and spoiled in a damp atmosphere. The use in dyeing is not attended with the same objections, and I have seen them largely used by a dyer in Bradford, England, who told me they obtained from dividivi a better black than from any other tannin material.

Myrobalans (*Terminalia Chebula*).—The fruit of a tree, forty to fifty feet in height, indigenous to India. This, like dividivi, is much used in dyeing and for toning the color of other tanning or dyeing materials. The amount of tannin is from forty to forty-five per cent.

Valonia (*Quercus Ægilops*) —This oak tree grows in the vicinity of the Mediterranean, and we obtain from it the acorn-cup, which, when ground, gives us a most valuable tanning material, imparting to leather both firmness and weight. When used alone, it renders the leather too hard and brittle, so that it is largely used in connection with myrobalans and mimosa.

Leaves.—Sumach is a name applied to various species of *Rhus*. In Europe, the *Rhus coriaria* is the most important, and furnishes to commerce the leaves which are so much esteemed by dyers, and for certain kinds of tanning. This small tree, or shrub, grows extensively in the countries bordering on the Mediterranean, and especially in Sicily. Contrary to the experience in the United States, it is said to flourish best in a limestone soil. From 10,000 to 12,000 tons are said to be annually imported of this variety. Of course, it has been suggested that we cultivate our own, as several species grow wild in this country.

R. glabra and *R. copallina* have been recommended for this in

addition to the Sicilian. Considerable attention has been given to this subject by our Government, and valuable reports were published in regard to it in the Agricultural Reports for 1878 and 1881–82.

The plants are propagated from the young shoots which are found each year about the base of the older plant. These shoots are planted very much in the manner adopted for potatoes, and the cultivation is conducted similarly to that applied to Indian corn. They are planted in the spring, and when well started are cut down to within six or eight inches of the ground. The second summer they will yield a crop of leaves.

The leaves are gathered either by cutting the small branches, or by stripping directly, leaving the small leaves on the ends of the shoots. A plantation is said to yield profitable crops for ten years. The average yield is 2,600 pounds per acre. After the second year, the leaves are more valuable. When the collecting is accomplished by cutting, the branches are allowed to wither, and are then carried to a shed and dried. The drying must be conducted carefully, in order to prevent heating and consequent fermentation and spoiling.

The branches when dry are beaten with a flail, and the leaves separated by sifting. When ground, the leaves are ready for market. The grinding is accomplished by heavy stones set on edge. Virginia is the state in which most attention has been devoted to this industry, and the crop reaches 7,000 to 8,000 tons. There is said to be a difference between the American and European products. The former yields from six to eight per cent. more tannin, but the accompanying yellow or dark color is a great objection to those who wish to have a fine white leather. This color is supposed to be identical with the quercitron in oak bark. The Government chemists have decided that this coloring matter exists in larger proportion in the leaves collected late in the season, consequently it is recommended to collect not later than the last of June. The amount of tannin reaches its maximum in July, but it is thought best to sacrifice this small amount, being 22·75 per cent. in June against 27·38 per cent. in July. The Sicilian product yields 24·27 per cent. of tannin. There are many difficulties in the way of sumach becoming a universal tanning material, a very considerable one is the tendency which the infusion possesses of becoming sour. This has been obviated by the use of extract of sumach,

which has been deprived of much of its coloring matter, and consequently is better in two ways.

The process consists in adding to the thin liquor, which has been run from the extractors into a large tank, oxalic acid in the proportion of one gram to 100 litres: this saturates the lime which has come from the water used in extracting. Gelatinous alumina (aluminium hydrate) is then added in the proportion of 250 grams to 100 litres. On filtering, a clear tannic extract is obtained, which is evaporated in vacuo to the desired consistency. I have examined such an extract, and found it very rich in tannin Mucilage may also be removed by increasing the amount of alumina to four times that above-mentioned. Such a process might be advantageously employed in this country for removing coloring matter from the infusions of sumach, which would admit of the leaves being gathered in July, when the proportion of tannin is the greatest. There are no means of knowing the exact amount of sumach produced in this country, but at least as much is gathered here as is imported, and probably a great deal more. This industry will undoubtedly become a very important one, for when the oak and hemlock fail, we must look to artificial growing for our tannin supply, and sumach is by far the most promising source for this object.

Canaigre root has also been considered as a possible tannin supply. The plant, *Rumex hymenosepalum*, from which the roots are obtained, grow abundantly in a large part of Texas. The roots are in clusters, like sweet potatoes, weighing several pounds, and are quite fleshy, but become much wrinkled in drying. When dried, they are said to yield forty per cent. of tannin, and as at present they grow on waste ground, they are worth our consideration as a supply. There is, however, considerable red coloring matter present, which may limit their use.

Cutch is a dried extract from *Acacia catechu*, a tree thirty to forty feet in height, indigenous to India, Burmah, and East Africa, and from *Acacia suma*, growing in South India and Bengal. The extract is prepared by cutting the trees when they are one foot in diameter, reducing all the woody parts, except the small branches, to chips, and digesting these chips in water in earthen vessels over slow fires. When sufficiently thickened after decantation and further concentration, the extract is poured into rude clay moulds or mats, and allowed to harden, in which form it comes into commerce.

Gambier is another variety, being an extract of the leaves of *Uncaria gambier* and *U. acida*, a climbing shrub indigenous to Ceylon and Sumatra. The leaves and young shoots are exhausted by boiling with water, the decoction is evaporated to the consistence of a syrup, when it is placed in buckets, a man plunges two sticks into two of these buckets, and works them up and down until the mass sets, a result which could not, it is said, be attained in any other way. This thick, yellowish mass, resembling clay, is poured into shallow boxes, cut into small cubes and dried in the shade. The importation of cutch, all varieties, in 1880, reached 23,000 tons, while in 1882 it fell off to 7,000 tons. England imports about 20,000 tons annually of gambier alone.

Polygonum amphibium, water knotweed, has attracted some attention as a source of tannin in Illinois, where it has been used by a few tanneries.

To summarize, it may be said that the future supply of the imported tannin-furnishing materials is not likely to become a concern to us, as the supply is either well nigh inexhaustible, or else the product of cultivation. We cannot afford, however, to depend on foreign supply to furnish material for the tanning and dyeing industries, consequently our own resources must be taken care of, or developed. At present, the hemlock, oak and chestnut give us all we need, but as this supply will soon be exhausted unless provision for a continuation of it is made, we must face the necessity of artificial sources at no distant date.

The sumach has already become a reality among the artificial sources, to be followed by such promising materials as mangrove and mimosa, which, having objectionable features, will have to be studied so as to adapt them to our needs.

A NEW PROCESS OF CASTING IRON AND OTHER METALS UPON LACE, EMBROIDERIES, FERN LEAVES AND OTHER COMBUSTIBLE MATERIALS.

BY A. E. OUTERBRIDGE, JR.

[*Abstract of Remarks made at the Stated Meeting of* THE FRANKLIN INSTITUTE, *Wednesday, April 20, 1887.*]

JOSEPH M. WILSON, President, in the Chair.

MR. OUTERBRIDGE:—The art of making charcoal—if, indeed, so crude a process is worthy of being dignified by the name of an art—dates back to a remote antiquity, and has been practised with but little change for hundreds of years. It is true that some improvements have been recently made, but these relate to the recovery of certain volatile by-products which were formerly lost.

Every one is familiar with the appearance and characteristics of ordinary charcoal, yet I hope to show you this evening that we still have something new to learn about its qualities and the unexpected practical uses to which it may be applied.

We commonly regard charcoal as a brittle, readily combustible substance, but we have before us specimens in which these qualities are conspicuously absent. Here is a piece of carbonized cotton sheeting, which may be rolled or folded over without breaking, and, as you see, when placed in the flame of a Bunsen burner, the fibres may be heated white-hot in the air, and when removed from the flame, the material shows no tendency to consume. Here, again, we have a piece of very fine lace, which has been similarly carbonized, and displays the same qualities of ductility and incombustibility.

These carbonized fabrics may be subjected to much more severe tests with impunity, and, when I tell you that they have been exposed to a bath of molten iron without injury, you will readily admit that they possess some qualities not ordinarily associated with charcoal. When removed from the mould in which they were placed after the iron casting had cooled, not a single fibre was consumed, but *upon the face of the casting there was found a sharp and accurate reproduction of the design, thus forming*

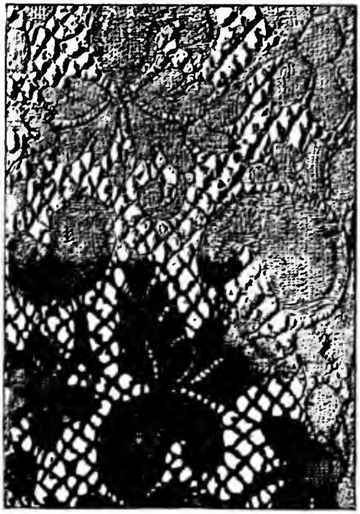

FIG. 1.

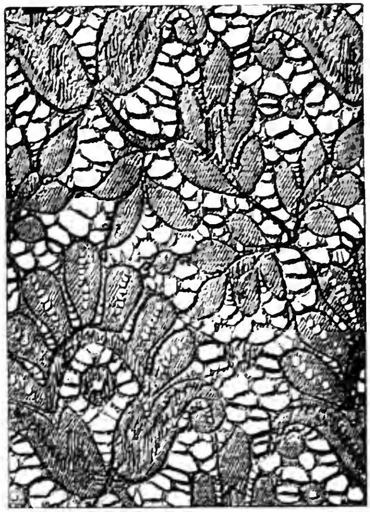

FIG. 2.

FIG. 3.

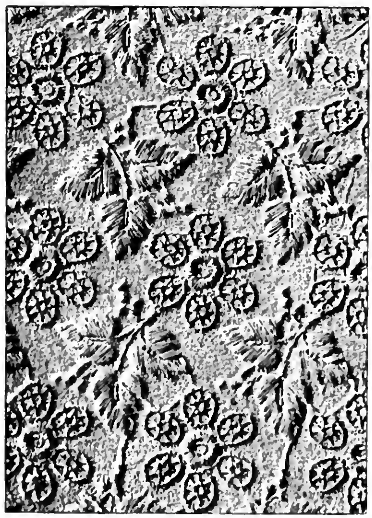

FIG. 4.

NOTE.—*Fig. 1* is photographed from a white iron casting made upon carbonized coarse lace, the lower portion of the plate shows the lace imbedded in the iron. *Fig. 2* is a casting in gray iron upon lace laid on an iron plate. *Fig. 3* is a casting in hard iron upon lace laid on sand. *Fig. 4* is a casting in gray iron upon a piece of thin summer dress goods with machine embroidery.

a die. This die may be used for a variety of purposes, such as embossing leather, stamping paper, sheet metal, etc., or for producing ornamental surfaces upon such castings.

Some of the carbonized fabrics displayed upon the table are almost as delicate as cob-webs, and one would naturally suppose that when a great body of molten metal is poured into a mould in which they are placed, they would be torn to fragments and float to the surface even though they were unconsumed, yet such is not the case. I have found in practice that the most delicate fabrics may be subjected to this treatment without danger of destruction, and that no special care is needed either in preparing the mould or in pouring the metal.

By the aid of the megascope, the enlarged images of some of these castings, showing the delicate tracery of the patterns, will now be projected upon the screen, and you can all see how perfectly the design is reproduced.

In these experiments, the mould was made in "green sand" in the ordinary manner, and the fabric laid smoothly upon one face, being cut slightly larger than the mould, in order that it might project over the edge, so that when the moulding-flask was closed, the fabric was held in its proper position. As the molten metal flowed into the mould, it forced the fabric firmly against the sand wall, and when the casting was removed, the carbonized fabric was stripped off from its face without injury. In this way several castings have been made from one carbonized material.

These castings are as sharp as electrotypes, whether made of soft fluid iron or of hard quick-setting metal. This peculiarity is owing to the affinity between molten iron or steel and carbon, the molten metal tends to absorb the carbon as it flows over it, thus causing the fabric to hug the metal closely. It is somewhat analogous to the effect of pouring mercury over zinc. You know that when mercury is poured upon a board, it runs in a globular form, it does not "wet" the board, so to speak, but when poured upon a plate of clean zinc, it flows like water and wets every portion of the zinc; or, as we say, it amalgamates with the zinc; so when molten iron is poured into an ordinary sand mould, which has been faced with this refractorily-carbonized fabric, it wets every portion of it, tending to absorb the carbon, and doubtless would do so if it remained fluid long enough, but as the

metal cools almost immediately, there is no appreciable destruction of the fibres.

The casting which I shall now exhibit represents a very intering and novel experiment. In this case, the piece of lace, having open meshes a little larger than a pin's head, instead of being laid upon one face of the mould, was suspended in it in such a way as to divide it into two equal parts. Two gates or runners were provided, leading from the "sinking head" to the bottom of the mould, one on each side of the lace partition, the molten iron was poured into the sinking head and flowing equally through both runners, filled the mould to a common level. The lace, which was held in position by having its edges imbedded in the walls of the mould, remained intact. When the casting was cold, it was thrown upon the floor of the foundry and separated into two parts, while the lace fell out uninjured, and the pattern was found to be reproduced upon each face of the casting.

The question naturally arises, why did not the iron run through the holes and join together? The answer may be found in the fact that the thin film of oxide of iron or "skin," as it is popularly called, which always forms on the surface of molten iron, was caught in these fine meshes, and thus prevented the molten metal from joining through the holes. I have repeated the experiment a number of times, and find that the meshes must be quite small (not over one-fiftieth of an inch) otherwise the metal will reunite.

I think that this observation explains the cause of many obscure flaws found in castings, sometimes causing them to break when subjected to quite moderate strains. We frequently find little "cold shot," or metallic globules, imbedded in cast iron, or steel, impairing the strength of the metal, and it has long been asked, "What is the cause of this defect?" The pellicles have been carefully analyzed, under the supposition that they might be alloys of iron and nickel, or some other refractory metal, but the analysis has failed to substantiate this theory. Is it not probable that in the process of casting little drops of molten metal are sometimes splashed out of the stream, which immediately solidify and become coated with a skin of oxide, then falling back into the stream of rapidly cooling metal, they do not remelt, neither do they weld or amalgamate with the mass owing to this protective coating, thus forming dangerous flaws in the casting?

The process of carbonizing the delicate fabrics, leaves, grasses, etc., is as follows: the objects are placed in a cast-iron box, the bottom of which is covered with a layer of powdered charcoal or other form of carbon, then another layer of carbon dust is sprinkled over them, and the box is covered with a close-fitting lid. The box is next heated gradually in an oven, to drive off moisture, and the temperature slowly raised until the escape of blue smoke from under the lid ceases, the heat is then increased until the box becomes white hot, it is kept in this glowing condition for at least two hours; it is then removed from the fire, allowed to cool, and the contents are tested in a gas flame. If they have been thoroughly carbonized, they will not glow when removed from the flame, and the fibres may even be heated white hot before consuming.

Of course, the method employed to carbonize the materials is suspectible of variation, but the scientific principles involved are unchangeable, viz.:

(1.) Partial exclusion of air and substitution therefor of a carbon atmosphere.

(2.) Slow heating to drive off moisture and volatile elements.

(3.) Intense and prolonged heating of the partly charred objects to eliminate remaining foreign elements, and to change the carbon from the combustible form of ordinary charcoal to a highly refractory condition.

EDITOR'S NOTE.—The description of this novel process elicited some interesting discussion, and the exhibition of fine castings on the delicate fabrics called forth much approbation. Several practical applications of the process have been suggested.

Note on the MODIFICATIONS of the BESSEMER STEEL PROCESS.

By C. Hanford Henderson.

[*Abstract of a Lecture, delivered before the* Franklin Institute, *Monday, January 3, 1887.*]

In the ordinary pneumatic steel process, there are four elements which are susceptible of essential modification. These are:

(1.) Shape of the converter.

(2.) Nature of lining.

(3.) Composition of metallic charge.

(4.) Composition of blast.

In glancing over this table, it may possibly be thought that two very important factors have been omitted,—those of time and temperature. But they are both involved in the four elements cited. The time of the reaction will depend upon the chemical composition of the lining, of the metallic charge and of the blast. It is assumed in each case to be such as will give the best results. The temperature at which these reactions occur is dependent upon the calorific power of the oxidizable elements, and is therefore quite beyond our control when once the composition of the metallic bath has been decided upon.

In the regular Bessemer process, the shape of the converter, it will be remembered, is simply that of a bulging vase, with the tuyères or blast holes in the bottom. The vessel is generally movable about a horizontal axis through 180°, but occasionally it is fixed. Since the chemical reactions are the same in both cases, however, these differences of construction are in no sense distinctive, and may be omitted from such a general consideration as the present. The lining of the converter is of gannister, and consequently highly acid. During the progress of the "blow," the molten oxide of iron, coming in contact with the silica of the lining, unites with it to form a fusible slag of silicate of iron. As the lining furnishes an unfailing supply of silica, there is always an excess of that element available, and the slags in the regular Bessemer operation are invariably very acid. The phosphorus in the

pig iron is therefore all retained in the resultant steel. It manifests itself in even higher proportion than in the original crude material, since there is a loss of about ten per cent. during the transformation of iron into steel. The nature of the lining has given the name of acid process to the typical Bessemer operation. This designation is now in constant use in order to distinguish the older process from the basic process, invented by Messrs. Thomas and Gilchrist. The metallic bath in the regular Bessemer consists of a very pure pig iron, containing from 0·77 to 3·0 per cent. of silicon, and from 3·50 to 4·70 per cent. of carbon, with but traces of phosphorus and sulphur. The blast used to burn out the carbon and silicon from the pig metal is simply air, just as it exists in the atmosphere.

Such are the four elements that go to make up the Bessemer process. The modifications of that process, which are possible, will all come under the several headings given, and may advantageously be considered in the order in which the elements have been mentioned. At the present time, these modifications possess more than a passing interest, since several of them are of large importance, commercially. Much ingenuity has been expended in the effort to so vary the shape of the converter that a new and distinctive process might be announced. But, in spite of the fancied merits claimed for these inventions, they are, for the most part, modern revivals of old and discarded devices. At the October meeting of the British Iron and Steel Institute, Sir Henry Bessemer read a very interesting paper, in which he described some of the earlier forms of his converter. The diagrams which he exhibited, showed conclusively that he had, at the very inception of his process, made an exhaustive study of the possibilities in the direction of form. Many of the modified converters now being brought forward by later patentees are almost exact reproductions of those abandoned by Bessemer years ago, on account of their manifest inferiority to the typical vessel which bears his name. It would, therefore, be a fruitless inquiry to consider all of the varied shapes which have been impressed upon the pneumatic steel converter. At the present time, there is but one modification which has any strong claim upon the attention of American metallurgists, and that is the form introduced into this country under the name of its British patentees, Messrs. Clapp and

Griffiths, but which, in reality, owes whatever orignality it may possess to its American adapter, Mr. James P. Witherow, of Pittsburgh. The importance of even this converter is commercial rather than technical. While the history of its development here may show that under certain economic conditions, it possesses advantages over the usual Bessemer plant, a candid examination of the Clapp-Griffiths vessel fails, I think, to discover any features which sufficiently differentiate it from the typical Bessemer converter to permit one to rank the operations carried out in it as a distinctive process.

Briefly described, the Clapp-Griffiths converter is a stationary vessel having the tuyère holes in the side some distance above the bottom, and provided above these with a charging door and open slag hole. Its capacity varies from a few hundred pounds of metal to several tons. In general, the preference is given to small charges, or to such as do not exceed two or three tons. The essential features in its operation are the side-blowing and the continuous slagging. It is of no importance that the vessel is stationary, since it is not always so constructed, and since the regular Bessemer converter used in several Swedish localities is of the same design. The Clapp-Griffiths blow is characterized by the almost immediate appearance of copious reddish-brown fumes of oxide of iron, indicating an early oxidation. As the molten bath stands only about eight inches above the level of the tuyères, the blast has a comparatively shallow depth of metal to penetrate. As a result of this construction, large quantities of iron are readily oxidized and the slags formed have a much higher basicity than is customary in the regular Bessemer practice. The open slag-hole, by permitting the removal of the slag during the boil, also favors this result. By withdrawing the silicate of iron as it forms, an excess of oxide of iron is ensured, and the conditions for the subsequent reduction of the silicon are made less favorable. The resultant metal is consequently low in both carbon and silicon. It contains, however, nearly all of the phosphorus carried by the original pig iron. It is a recognized fact in the metallurgy of steel that phosphorus becomes, if not entirely innocuous, at least a much less undesirable constituent when dissociated from carbon and silicon. This is believed to be the explanation of the remarkable physical tests endured by highly phosphoric samples of Clapp-

Griffiths metal, for it is invariably low in silicon. Captain Hunt's much quoted results showed that steel containing as much as one-half of one per cent. of phosphorus was in reality an admirable material if only carbon and silicon were reduced to a minimum. But whether the deeply-rooted prejudice against phosphoric products made them unpopular, or whether the difficulties in the way of their introduction were of a more inherent nature, it would be hard to say. At the present time, however, pig irons of more than moderate phosphoric content are not being employed by the Clapp-Griffiths plants. The result of blowing a charge in such a converter may be stated then to be a soft ingot iron which is of better quality for the same grade of pig metal than if blown in the larger vessel. So much for the product, but we want more particularly to know about the process. The pertinent question presents itself as to whether the same result might not have been obtained by a more careful attention to the conditions in the typical Bessemer converter. The question will best be answered by observing the result obtained at plants where the conditions are more nearly comparable with the conditions prevailing in the Clapp-Griffiths. Such a comparison has been made easy by Prof. Drown, who, in his paper on "The Little Bessemer," cites the results from a number of European establishments, where the blowing of small charges is regularly practiced. From this it appears that while the behavior of highly phosphoric pig metal in acid-lined converters, other than the Clapp-Griffiths, has not been made the subject of inquiry, the same minima of carbon and silicon in the resulting steel is obtainable if care is taken to maintain an excess of oxide of iron in the slag, by having but a small depth of metal above the tuyéres. In the large Bessemer converter, blowing charges of ten or fifteen tons, low silicon is sometimes produced, but it cannot be depended upon, while in the little Bessemer such a result may be made invariable.

But while the Clapp-Griffiths is a modification in no way distinctive, either in its mechanical features or in the quality of its product, it has an importance, commercially, which must not be lost sight of. The first cost of the plant is comparatively small, and will frequently justify its erection under circumstances which would otherwise be prohibitive. It is improbable that it will ever be able to compete with the regular process in the production of

the larger articles in the steel industry, but as an adjunct to the blast furnace, for transforming the product into ingot iron or steel, or for supplying a special market, removed some distance from the great centres of steel production, the future apparently offers many encouraging possibilities. It is, I think, detracting nothing from the just rank of this converter, and the process carried out in it, to consider it simply a judicious adaptation of the small vessel to the needs of our home metallurgy. But whether it fulfil its present promise of usefulness in this country or not, American engineers have certainly been placed under much obligation to those who have, in the face of many difficulties, introduced the process here, and brought about the current and widespread discussion concerning the influence of early oxidation of the iron, and of mass, in determining the qualities of the resultant steel.

In considering the modification of the Bessemer practice, due to a changed lining of the converter, we are brought to a process which, by virtue of its characteristic chemical reactions, is entitled to the rank of a distinct invention. Its importance may be judged from the fact that over 1,000,000 tons of steel are now annually manufactured by the works where it has been introduced. In the regular Bessemer operation, as has been stated, the lining of the converter is highly acid, and, in consequence, no phosphorus is eliminated from the pig metal during its conversion into steel. This condition limited the crude material available for the process to the irons containing little or no phosphorus. To so modify the conditions, that an acceptable steel could be made from phosphoric pig metal, has been the chief problem before the metallurgical world since the first announcement of Bessemer's great discovery, but its solution was not accomplished until 1878.

In that year, Mr. Sidney Thomas announced to the British Iron and Steel Institute that he had, with the co-operation of Mr. Percy Gilchrist effected the removal of phosphorus in the Bessemer converter, by substituting a basic lining for the usual gannister. When phosphoric pig metal is subjected to a blast of air, the phosphorus oxidizes and forms phosphate of iron, but at the high temperatures prevailing in the converter, it is readily replaced by silicon, if that element be present, and is again reduced to phosphide of iron This fact was well known to metallurgists, but the simple expedient of preventing the subsequent reduction of the

phosphorus, by keeping silicon out of the way, does not seem to have made much impression upon them, until Messrs. Thomas and Gilchrist carried out the suggestion experimentally and demonstrated its entire practicability as an industrial operation. In the process, which bears their name, the converter is of the usual form, and is lined with burnt dolomite, a mixture of the oxides of calcium and magnesium. The metallic charge differs in containing but very small amounts of silicon, and carrying preferably about three per cent. of phosphorus. From twelve to fourteen per cent. of lime is thrown into the converter just before the introduction of the metallic charge. The progress of the blow in the basic operation is precisely the same as in the regular Bessemer, except that the charge is subjected to an "after-blow," during which the elimination of the phosphorus is accomplished. On account of the low percentage of silicon, the Bessemer blow, as it is termed to distinguish it from the after-blow, requires much less time than ordinarily, occupying frequently not more than about eight minutes. Another consequence of the low silicon is that the charge is apt to blow cold. It is, therefore, customary to heat the pig metal in a regenerative furnace before its introduction into the converter, so that the initial temperature may be as high as possible. When the flame drops, indicating the complete removal of carbon, the blast is continued for, perhaps, five minutes longer, or in general, about two-thirds of the time required by the Bessemer blow. During this period, the appearance of the flame remains unchanged, and the spectroscope shows only the sodium line. The termination of the after-blow is indicated by no marked reaction. It must be determined entirely by special tests. A sample of the steel is taken from the converter, rapidly cooled and the fracture subjected to a careful examination. To the practiced eye, the crystalline structure follows very closely the phosphoric content, and may frequently supplant chemical analysis. In Silesia, the deepening color of the slag is made the criterion of the progress of the after-blow. When this is ended, from one-half to one per cent. of ferro-manganese (eighty per cent. manganese) is added to recarbonize the charge. The ferro-manganese is generally heated, and half added in the converter and the remainder in the ladle; but these smaller details of management naturally vary at each establishment. The *rationale* of the Bessemer blow is too well

known to require comment, but the after-blow is a less familiar operation. The following analyses, obtained from gentlemen who have spent some months in experimenting with the basic process, will offer a good foundation for discussing the reactions of the after-blow:

CONVERTER LINING.

Silicon,	2·00
Magnesia,	29·50
Lime,	62·60
Iron and alumina,	1·30
Moisture and carbon dioxide (by difference),	4·60
	100·00

PIG METAL.

Silicon,	·60
Sulphur,	·05
Phosphorus,	2·50
Manganese,	·25
Carbon,	3·50
Iron (by difference),	93·10
	100·00

BASIC FLUX.

Lime,	93·80
Magnesia,	3·00
Silica,	1·50
Iron and alumina,	1·20
	99·50

BASIC STEEL.

Carbon,	·06
Silicon,	·01
Sulphur,	·05
Phosphorus,	·06
Manganese,	·25
Iron (by difference),	99·57
	100·00

BASIC SLAGS.

	I.	*II.*	*III.*	*IV.*
Silica,	7·20	16·00	6·00	8·43
Phosphorus,	7·42	5·49	7·80	8·31

When the Bessemer blow ends, the metal in the converter consists of an almost completely decarbonized and desiliconized iron carrying from three to four per cent. of phosphorus. During the

after-blow this element is oxidized and becomes the heat producer of the operation. Phosphate of iron is formed and floats upon the bath as a fusible slag. The iron, however, is speedily displaced by the more powerful bases, lime and magnesia. The comparative absence of silicon, for it will be noticed that in lining, pig metal and flux, the amount of that element has been reduced to a minimum, prevents the subsequent reduction of the phosphorus and its combination with the iron as a phosphide. The product of the basic operation is a very soft steel containing not excessive amounts of phosphorus. The economic feature of the process is the production of an excellent steel from a cheap pig iron; perhaps its greatest disadvantage, the difficulty of maintaining a sufficiently high temperature in the presence of such low silicon.

In the conduct of the process, the lining for the converter is prepared by mixing the ground dolomite with about eight per cent. of anhydrous tar. The Holley movable bottom is used in the most modern establishments, the tuyères being constructed of fine clay as in the ordinary process. The average life of the bottoms is forty blows, and of the vessel itself twice that number. It is very desirable that the pig iron shall be high in phosphorus, since the final heat and consequent fluidity of the steel depend upon the oxidation of this element. In the analysis quoted, the phosphorus was only two and one-half per cent., but three, or even three and one-half per cent., is preferable. The slags from the basic process possess no little value for the manufacture of super-phosphates. They find always a ready market, as it requires only fine grinding to make the phosphorus directly available as a plant food.

At the present time, the Thomas-Gilchrist process is in active operation in Germany, Austria, England, France, Belgium and Russia; in all of the great iron-producing countries, indeed, except the United States. It is an open secret that experiments are now in progress in this country, but as yet the operations in this direction have been decidedly spasmodic. The abundance of Bessemer ores can scarcely be adduced as an explanation of the cause of this lack of development, since phosphoric ores, it need hardly be said, are far more abundant, and sufficiently lower in price to make their utilization a profitable operation. Particularly is this the case in the South, and southern iron-masters are finally turning their attention to the basic process as the probable

development best suited to their local conditions. The cause of American inaction is rather to be found in the litigation, which unhappily surrounded the process in this country from almost the first day of its announcement.

The third direction in which the Bessemer process may be modified, is in the composition of the metallic bath, but no distinct process has been founded upon this variation. It is involved alike with the changed lining in the basic operation, since the pig metal must necessarily be low in silicon and high in phosphorus. Nor has the possibility of changing the composition of the blast been as yet more productive in giving us a practical modification. In the earlier days of the process, a number of suggestions were brought forward for replacing the air in whole or in part by hydrogen gas and by steam, the idea apparently being that the affinity of hydrogen for phosphorus and sulphur would cause a union with those elements and partially remove them in the form of gases. But while nascent hydrogen at lower temperatures readily effects the decomposition of solid phosphides and sulphides, carrying off the phosphorus and sulphur in the form of phosphuretted and sulphuretted hydrogen, the unstable character of these products leaves little ground for hope that such reactions could be made of any value in the Bessemer converter. Experiments made in this direction have never met with any success, but since nothing is so sure as the unexpected, it would be premature to affirm that the field had been exhausted.

It is apparently the tendency in modern Bessemer practice to produce steels low in silicon and carbon, to replace as far as possible wrought-iron as a constructive material. It is always dangerous for the worker in the laboratory and among books to predict what his brother-worker at the furnace will or will not do, but if one who stands afar off may presume to judge, the possibility which will attract the study of future steel-makers, will be the production of a neutral lining permitting basic or acid slags at pleasure.

Philadelphia Manual Training School, January 3, 1887.

The CASTNER SODIUM PROCESS.

By Mr. James Mactear, F.C.S.

[*An Address read at the meeting of the Society of Chemical Industry, London, March 7, 1887.*]

Having been engaged professionally during the past few months in assisting in the development of this process, through the kind permission of Mr. Castner, I am enabled to present to this Society, its details, together with a few facts concerning the uses and cost of manufacturing sodium and potassium.

The process heretofore exclusively used for the production of these two metals is so well known that anything more than a brief reference is hardly necessary in this paper.

By the older process, carbonate of soda, charcoal, and lime, in proportion of thirty, thirteen and seven, are made into the finest and most intimate mixture, and then calcined at a red heat to render the mixture more compact, which also expels a considerable amount of carbonic oxide. This calcined mixture is then introduced into wrought-iron cylinders of small diameter, and heated to a temperature of about 1,400° C., whereby the alkaline metal is reduced and distilled from the cylinder containing the charge, through a small tube provided for the gases and vapors, into the receptacle known as the condenser. Through a variety of causes, not more than forty per cent. of the metal contained in the charge is obtained, and in the manufacture of potassium very much less. The wear and tear on the metal cylinders is enormous, and forms a large proportion of the cost of manufacture. To arrive even at these results, requires—

(1.) The most careful grinding and mixing of ingredients.

(2.) The addition of lime to prevent fusion.

(3.) An excess of carbon to ensure contact between the particles of soda and carbon in the refractory charge.

(4.) Previous calcination to make the charge less bulky.

(5.) Wrought iron must be used in constructing the cylinders, being the only available metal that will stand the high temperature.

(6.) Cylinders must be used for small diameter, so as to allow the heat to penetrate to the centre of the refractory charge.

(7.) The exit tubes from the cylinders to the condensers require the most careful attention, to keep them open, owing to the formation of the black compound, formed by the action of carbonic oxide upon the vapor of the alkaline metal, which combination takes place at about the condensing point of the metallic vapor. This is one of the most serious obstacles to be met with in the course of manufacturing sodium, not only causing a large loss of metal, but interfering generally with the operation. In the making of potassium, the formation of this compound, which is exceedingly explosive, and which is produced even more readily than when making sodium, is the chief reason that this metal costs almost ten times as much as the same quantity of sodium.

As nearly as I can ascertain at present, sodium costs about four shillings per pound to produce, the following being the chief items:

	s.	*d.*
Wear and tear to furnaces, cylinders, etc., ...	2	0
Materials—owing to loss and waste, ...	1	0
Labor, ...	0	8
Fuel, ...	0	4

Since Mr. Castner's paper upon his process, which was read* before the FRANKLIN INSTITUTE of Philadelphia, October 12, 1886, several slight changes in the mode of carrying on this process have been made. These have been brought about by the experience gained from the actual working of the process upon a commercial scale.

The reactions by which the sodium and potassium are produced are difficult to describe, as they vary somewhat according to the mixture of materials and temperature employed in the reduction. The mixture and temperature which it is now preferred to use, is represented by the reaction:

$$6\ Na\ HO + Fe\ C_2 = 2\ Na_2\ CO_3 + 6\ H + Fe + 2\ Na$$
$$6\ KHO + Fe\ C_2 = 2\ K_2\ CO_3 + 6\ H + Fe + 2\ K$$

In place of using an actual chemical compound of iron and carbon, as expressed by the above reaction, a substitute or equivalent is prepared as follows: To a given quantity of melted pitch is added a definite proportion of iron in a fine state of division. The mixture is cooled, broken up into lumps and coked in large crucibles, giving a metallic coke, consisting of carbon and iron, the proportions of each depending upon the relative quantities of pitch

* See this JOURNAL, **122**, 347.

and iron used. This metallic coke, after being finely ground, provides a substance having the iron and carbon in a like proportion to an iron carbide, and from which neither the iron nor carbon can be separated by mechanical means. The fine iron is conveniently prepared by passing carbonic oxide and hydrogen in a heated state, as obtained from an ordinary gas producer, over a mass of oxide of iron, commercially known as "purple ores," heated to a temperature of about 500° C.

In producing sodium, caustic soda of the highest obtainable strength is used, and there is mixed with it a weighed quantity of the so-called "carbide," sufficient to furnish the proper amount of carbon to carry out the reaction indicated above. The crucibles in which this mixture is treated are made of cast steel, and are capable of containing a charge of fifteen pounds of caustic soda, together with the proper proportion of the "carbide."

After charging a crucible with the above mixture, it is placed in a small furnace, where it is kept at a low heat for about thirty minutes, during which time the mass fuses, boils violently, and a large part of the hydrogen is expelled by the combined action of the iron and carbon, the "carbide," owing to its gravity, remaining in suspension throughout the fused soda. At the end of the time stated, the contents of the crucible have subsided to a quiet fusion. The crucible is then lifted, by a pair of tongs on wheels, placed upon the platform of the elevating gear, and raised to its position in the heating chamber in the main distilling furnace. The cover which remains stationary in the furnace has a convex edge, while the crucible has a groove round the edge, into which the edge of the cover fits. A little powdered lime is placed in the crucible groove just before it is raised, so that when the edges of the cover and crucible come together, they form a tight joint, and, at the same time, will allow the crucible to be lowered easily from the chamber when the operation is finished, to give place to another containing a fresh charge. From the cover projects a slanting tube connected with the condenser. The condenser is provided with a small opening at the further end, to allow the escape of hydrogen and has also a rod fixed by means of which any obstruction which may form in the tube, during distillation, may be removed. After raising a crucible in its place in the furnace, the hydrogen escaping from the condenser is lighted, and

serves to show by the size of the flame how the operation is progressing in the crucible, the sodium actually distilling soon after the crucible is in its place. The temperature of the reduction and distillation has been found to be about 823° C. The gas coming off during the first part of the distillation, has been analyzed and found to consist of pure hydrogen. An analysis of the gas sample taken when the operation was almost completed, gave as a result, hydrogen ninety-five per cent, carbonic oxide five per cent. It has been found advisable to use a little more "carbide" than the reaction absolutely requires, and this accounts for the presence of the small quantity of carbonic oxide in the expelled gas, the free carbon acting upon the carbonate formed by the reaction, thus giving off carbonic oxide, and leaving a very small percentage of the residue in the form of peroxide of sodium. This small amount of carbonic oxide rarely combines with any of the sodium in the tube, and so the metal obtained in the condensers is pure, and the tubes never become choked with the black compound. In the preparation of potassium a little less "carbide" is used than the reaction requires, thus no carbonic oxide is given off, and all danger attached to the making of potassium is removed. After the reduction and distillation, the crucible is lowered from the furnace, and the contents poured out, leaving the crucible ready to be recharged. The average analyses of the residues show their composition to be as follows:

	Per Cent.
Carbonate of soda,	77
Peroxide of sodium,	2
Carbon,	2
Iron,	19

The average weight of these residues from operating upon charges of fifteen pounds of caustic soda, and five and one-fourth pounds of carbide, is sixteen pounds. These residues are treated either to produce pure crystallized carbonate of soda or caustic soda, and the iron is recovered and used again with pitch in the formation of the "carbide." From this residue, weighing sixteen pounds, is obtained thirteen pounds of anhydrous carbonate of soda, equivalent to 9·4 pounds caustic soda of seventy-six per cent.

Operating upon charges as above mentioned, the yield has been:

	Pounds.
Sodium, actual,	2·50
" theory,	2·85
Soda, carbonate, actual,	13·00
" " theory,	13·25

The average time of distillation in the large furnace has been one hour thirty minutes, and as the furnace is arranged for three crucibles, forty-five pounds of caustic soda are treated every ninety minutes, producing seven and one-half pounds of sodium and thirty-nine pounds of carbonate of soda. The furnace is capable of treating 720 pounds of caustic soda daily, giving a yield, in twenty-four hours, of 120 pounds of sodium and 624 pounds of anhydrous carbonate of soda. The furnace is heated by gas, which is supplied by a Wilson gas producer, consuming one cwt. of fuel per hour. The small furnace, in which the crucibles are first heated, requires about one-half cwt. per hour. The following estimate of cost, etc., is given from the actual running of the furnace working with the above charges for twenty-four hours:

	£.	s.	d.
720 pounds of caustic soda @ £11 per ton, ...	3	10	10
150 " " "carbide" @ ½d. per pound, . . .	0	6	4
Labor, ...	1	0	0
Fuel, ...	0	17	0
Re-converting 624 pounds of carbonate into caustic at a cost of about £5 per ton on the caustic produced, say, ...	1	0	0
Total, ...	£6	14	2
Deducting value of 475 pounds of caustic recovered, .	2	6	8
Cost of 120 pounds of sodium, ...	£4	7	6

Cost per pound, 8¾d.

Regarding the item of cost relating to the damage caused to the crucibles by the heat, this question has been very carefully gone into. Some of the crucibles have been used upwards of fifty times, and from present indications of their condition, there is no doubt that they can continue to be used at least 150 times more before they become unfit for further use. In considering 200 operations to be the life of a crucible, the item of damage, or wear and tear, amounts to less than one pence per pound on the sodium produced, and, if we take the furnace wear and tear at the same rate of one pence per pound, we will see that the wear and tear of plant is only one-twelfth of that incurred in the ordinary process. It is upon these facts that Mr. Castner bases his claim to be able to produce sodium by his process, upon the large scale, at a cost of less than one shilling per pound. The advantages of this process will be apparent

to anyone at all familiar with the manufacture of these metals as conducted heretofore. The first and most important end gained is their cheap production, and this is owing chiefly to the low heat at which the metals are produced, the quickness of the operation, non-clogging of the conveying tubes, and a very small waste of materials. The process furthermore admits of being carried on upon a very large scale, in fact it is intended ultimately to increase the size of the crucible, so as to make the charges consist of fifty pounds of caustic soda. Crucibles of cast iron have been found quite suitable, and it is intended in future to use crucibles made of this material in place of the more expensive steel.

As regards potassium, it has hitherto been regarded very much as a chemical curiosity, and sells for about sixty shillings per pound. By this method the cost of the manufacturing operations is no more than for sodium, the higher cost of the caustic potash being the chief element of increased expense. The uses of these alkali metals are at present limited, owing to their high cost alone. Sodium is used somewhat largely in manufacturing aluminium, magnesium, silicon, etc., and in the formation of amalgams, while potassium is only used in small quantities as a chemical reagent. It will hardly be considered out of place, in concluding this paper, relating to the manufacture of sodium and potassium, to mention some few facts connected with aluminium. This metal depends at present upon sodium for its production, and consequently any process successfully producing *cheap* sodium in reality allows of the manufacture of *cheap* aluminium. Notwithstanding all the efforts that have been made by various chemists and metallurgists for the past thirty years in endeavoring to invent some process for producing aluminium, whereby that most interesting and valuable metal could be cheaply produced by a better process than that of Deville, absolutely nothing has been accomplished that would even lead one to hope that sometime in the future his process would be superseded. By employing Deville's process and using sodium as heretofore manufactured, the aluminium costs between thirty and forty shillings per pound. Owing to this high price alone, the consumption is limited, and therefore the manufacturer is obliged to ask in selling the metal a relatively higher price in order to obtain anything like a fair profit upon the invested capital. The present selling price of aluminium varies between fifty and sixty shillings per pound,

although every few months there appears in some newspaper the information that some parties (*unknown*) have contracted with other parties (*unknown*) for a large quantity of aluminium at prices varying between ten and thirty shillings per pound. It is needless to say that upon enquiring the contracting parties cannot be found.

Aluminium, if placed upon the market at twenty shillings per pound, could undoubtedly be sold in large quantities, the demand rapidly increasing as the metal gained in favor, which, owing to its varied valuable properties, it would do to a certainty. It is conceded by all those familiar with the different items of cost in carrying out Deville's process, that, could sodium be obtained for one shilling per pound, aluminium could be made below a cost of fifteen shillings per pound.

I think it is not therefore too much to claim for the "Castner Process" of manufacturing sodium and potassium—now that it has been demonstrated commercially capable of producing sodium at one shilling per pound—that it is the greatest advance in the direction of producing aluminium at a cheap rate, which has been made since Deville first demonstrated the possibility of producing that metal on a commercial scale.

It has long been known that the distillation of the metal sodium, is rendered more easy by the use of a proportion of potash in the mixture. It is also known that a series of alloys of potassium and sodium can be produced, several of which are liquid, having much the same appearance as mercury when under naphtha. These alloys are very curious, one of them remaining liquid at 0° C.; while another is lighter in its specific gravity than naphtha, upon which it floats.

Specimens of several of these alloys, together with samples of the sodium and potassium as made by this process, are upon the table, for your inspection.

On RANSOME'S IMPROVEMENTS in the MANUFACTURE of PORTLAND CEMENT.*

By R. J. Friswell, F.I.C., F.C.S.

Portland cement is composed of lime, silica and alumina in proportions approaching sixty, twenty-three and eight respectively; the remaining nine per cent. consisting of various non-essential substances, such as ferric oxide, three to five per cent.; calcium sulphate, 1·0 to 3·0 per cent.; clay and sand, 1·5 to 2·5 per cent.; together with varying quantities of magnesia, potash and soda, making between them about 2·5 per cent. It is what is known to technologists as a hydraulic lime or mortar, *i. e.*, one that possesses the valuable property of hardening under water, which it owes to the more or less intimate combination between the lime, silica and alumina present.

The orginal of this now world-renowned building material was the so-called "Roman" cement, first made by mixing the volcanic tufa of Puzzuoli, near Naples, with ordinary slacked lime. This tufa in its composition closely resembles burnt clay, and hence the idea of mixing clay with chalk and then burning the mixture gradually developed in succession to the burning of natural calcareous stones, such as the septaria nodules of the London clay beds, from which the English-made Roman cement was first produced. This comparatively easy step was patented by Mr. Aspdin, about the year 1824, who started works at Leeds, thus laying the foundations of the present enormous trade now principally centred round the valleys of the Thames and Medway. The process as it at present exists may be briefly described as follows: Chalk is mixed with the requisite quantity of clay in a "wash mill," a large circular basin of brick-work, in which a series of heavy iron drags or harrows are caused to rotate by the motion of a central spindle, to which they are suspended by radiating arms. Water is run in, and the two materials gradually disintegrate and thoroughly mix. The mixture, in the state of thin slop, known as "slurry," runs out of the mill as it is formed, and is led off to large settling tanks

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or ponds where it is allowed to remain at rest. The finely-divided chalk and clay settle down to a stiff mass at the bottom, and the water is run off; a series of tanks being so arranged that each one is ready for subsequent treatment about six weeks after it has been filled. The stiff mass, or "compo," left behind when the water has run off, is in many works removed and ground in an ordinary mortar mill, after removal from which it is loaded on to drying floors, which are heated, either with waste heat from kilns or coke ovens, or by special furnaces arranged for the purpose. A shed open at the sides protects the drying compo from rain, and it gradually solidifies into masses containing only a small percentage of moisture. These masses, varying from the size of a man's head to that of a fist, are placed in a kiln with alternate layers of coke. A fair-sized kiln will hold seventy tons of dried slurry, fifteen tons of coke, and a small quantity of brushwood to act as kindling.

The fire is now lighted, and by the fourth day, or in, say, ninety-six hours, the eighty-five tons of material have reached a temperature closely approaching that of molten cast iron, and have also diminished in weight to about thirty tons, plus the weight of the ashes of the coke (fifteen cwt.). The kiln requires a day to cool, another day to unload, and the thirty tons of hard cement clinker is ready to be crushed, and then ground into a marketable product. In addition to the above process, there are two modifications of the preliminary part of it in use, known respectively as the "semi-dry" and "dry" processes. These apply a less quantity of water in the mixing of the materials, the object being to do away with the settling tanks, and thus save space and labor. The treatment of the product in the kiln is, however, the same in all. It will be as well here to consider what has happened during the burning described above, and the first striking fact is the enormous decrease in weight. Firstly, the whole of the combustible portion of the coke has gone, mostly in the form of carbonic acid; secondly, the seventy tons of slurry have diminished to about thirty tons.

As far as the coke is concerned, assuming that ninety-five per cent. is carbon, the conversion of this into carbonic acid has involved the consumption of nearly thirty-eight tons of oxygen, equal to nearly 166 tons of air; next, the slurry has lost forty tons, thirty-eight tons being carbonic acid, and the atmosphere has thus

received from the kiln some ninety tons carbonic acid, 128 tons of nitrogen, and about two tons of water in the shape of steam. When the last of the coke has burned away, there is left in the kiln thirty tons of cement clinker at a temperature of over 2000° F., the walls of the kiln have also, for some distance from the interior, been heated to the same degree, and before anything can be done this mass must have become cool enough for removal. It is obvious that the heat retained after the clinker is formed is lost during this cooling process. The value of this heat is considerable, and would probably be equal to nearly one-third of the total coke consumed. In other words, it may be assumed that to re-heat thirty tons of clinker with the brick-work of the kiln would take five tons of coke. If this heat could be utilized, it would effect a saving of, say, two shillings per ton of cement made. Another defect of the process arises from the large size of the lumps of slurry put in. Owing to this they invariably consist of (1) an over-burnt exterior skin, (2) a properly-burnt inner part, (3) if at all large, of an under-burnt kernel. All these are of necessity ground together, since it is impossible to do more than make a very rough selection for the mill.

The clinker now cooled and ready for the mill is extremely hard. It has first to be crushed by a Blake's or other crusher to lumps about the size of a walnut, and these have to be ground under millstones. The extreme hardness of the material necessitates constant redressing of the stones to such an extent that at least a quarter of the stones in a cement mill are always "up" undergoing this process. Thus, while the steam-power required to deal with so refractory a material is a very heavy item, it is obvious that the maintenance of the mill in a thoroughly efficient state involves a constant and serious outlay. Another defect arises from the ash of the coke, which, being inextricably mixed with the cement clinker, is therefore ground with it and acts so far as an adulterant.

Returning to the kiln, we find that each firing involves the heating of the cold walls of the kiln to the necessary temperature, and again cooling them to the point at which it can be unloaded and again loaded up. The kilns have to be built of enormously massive masonry, to withstand the strains and racking caused by these constant violent changes of temperature. To keep them in

repair involves very heavy outlay, and the first cost of a thirty-ton kiln, of about 20 feet diameter and 35 feet to 40 feet high, with walls tapering from about three feet, with its fire-brick lining, is extremely heavy. The ground space occupied by it is also very large.

It will be seen from the above, that the processes of burning and grinding the cement are by far the most costly of all the operations involved in its manufacture, and that they are beset with defects, both scientific and practical, of a very serious nature. It is evident that if any great improvement is to be effected in the manufacture, that to these portions of the process the most serious attention must be directed. It is, therefore, to this part of the work that Mr. Ransome has directed his attention; taking as his guiding principles, economy of fuel, space and labor, he has devised the following process.

The slurry prepared by any one of the methods now in use, is dried on a floor heated as usual, or by waste gas from subsequent processes. The soft, friable and easily-crushed blocks are now reduced to coarse powder, and are then ready for burning. The old kiln is totally abolished, and in its place a cylinder of boiler-plate is used. This is lined with good refractory fire-brick set in fire-clay, and about every fourth row of bricks is set up on end, thus producing a number of parallel longitudinal feathers or ridges extending completely through the cylinder from end to end. The outside of the cylinder is provided with two smooth rings or rails of iron. In the centre a third rail is wrought into teeth, into which a worm rotated at a slow speed, gears. The two rails rest on friction rollers, and the whole cylinder being set at an angle with the horizon is caused to rotate slowly. This construction, though sounding somewhat formidable, is in practice extremely simple, and similar machines, known as "black-ash revolvers," or "revolving black-ash furnaces," have long been, and are now, in daily use in alkali works. The cylinder is mounted on the top of a brick-work chamber divided by interior walls of brick. The two outer chambers are filled with bricks piled in loosely, chequerwise, so as to present a large surface.

We will now suppose a cylinder to be started, and describe the operations. A gas producer being in working order and delivering its gas at a regular rate, it is lighted and the flame passes through

the cylinder, which in the course of a few hours attains a white heat. The waste heat from the revolver has also passed through and heated the right hand division of the regenerator to a bright cherry-red. A shunt valve is now opened, causing the waste gases to pass through the left-hand regenerator, while the gas from the producer is caused to flow through the heated right-hand chamber, and thus arrives at the mouth of the revolver already intensely heated. The result of this is that an immediate economy of fuel is produced, and to avoid overheat it will be necessary to reduce the gas supply. During the whole operation the air necessary for combustion is also heated by passing down a separate division of the regenerator, where it receives heat from the walls of the outer compartments. As soon as the right-hand chamber begins to cool, the furnaceman reverses his shunt valve and the fresh gas is turned through the hot regenerator, while the waste combustion products are heating that which has cooled down. The effect of this method of working is thus to return into the furnace the heat which, in ordinary methods of work, goes up the chimney. No startling innovation occurs save in the application of the method to cement making. Regenerative furnaces are in use all over the world, and an intelligent furnaceman will learn how to manage one in a few hours.

We have now to turn our attention to the cement which, taken from the drying floor, we described as crushed to a coarse powder. The powder is lifted by any convenient mechanical arrangement, to a hopper, placed at the upper end of the revolver; from this it falls in a steady shower *through the flame*, to the lower side of the cylinder, and lodges between the feathers. As the advancing side of the revolver rises, it is lifted until the feather attains such an inclination as to shoot it off again through the flame to the bottom once more, but, owing to the incline, several inches nearer to the lower end. As the revolver moves on, this operation continues again and again, the powder is constantly lifted and shot through the flame in showers, gradually getting nearer and nearer to the lower and hotter end of the cylinder, until at last it falls out into a receptacle at the lower end. In practice, it is found desirable to rotate the cylinder at such a rate that any given particle of cement takes about thirty minutes to travel from one end to the other, during which time it has been lifted and shot through the flame about fifty times.

The powder has now arrived at the outside of the furnace, and having been delivered on to a floor to cool, is at once ready for grinding; that is, it is in the same state as the clinker after being seven days in the kiln. Unlike cement clinker, however, it does not consist of lumps weighing from fourteen pounds downward, and as hard as granite, but of a coarse, roughly-agglutinated sand. Nor does it consist of an over-burnt skin, a properly-burnt inner portion, and a possibly under-burnt inmost part, but if the operation has been properly carried out, each fragment has been heated to exactly the proper degree. How exactly this heat can be regulated is well known to all who have ever used a regenerative furnace. Again, the fuel used is gaseous, consequently no mixture of coke ash has taken place, and the cement is really and in fact what it professes to be.

So much would have been achieved had the new process been introduced with a furnace which had to be cooled in order to remove its contents, but—and here comes in a source of immense saving, not only in fuel, but in repairs—this is not an intermittent but a continuous one. The revolver once started, goes on night and day delivering its hourly quantity of properly-burnt cement until its fire-brick lining requires renewing, an operation that only has to be performed occasionally. There is no constant loss of time and heat during cooling, loading and unloading, as with the kiln, but the hourly delivery of a ton of cement enables a works with two cylinders to turn out 336 tons of cement per week, a quantity that eleven kilns of the usual capacity could not produce in the same time. As a matter of prudent practice, the inventor advises that a spare cylinder with its regenerators should always be ready, so that a works using two cylinders would, as a fact, have three. In such a works, as soon as a revolver was seen to be in such a state as to require attention to its lining, gas would be turned on to the standing furnace, and in a few hours it could take up its duty, allowing the shut-down revolver to be repaired without any stoppage or diminution of the output. It is needless to say that the relining of a kiln is a very different matter, involving the loss of its services for many days.

(*To be continued.*)

THE JULIEN SYSTEM OF ELECTRICAL TRANSMISSION.

BY PEDRO G. SALOM, of Philadelphia.

[*A Paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *February 16, 1887.*]

JOS. M. WILSON, President, in the Chair.

MR. SALOM.—I take great pleasure in bringing to your attention this evening, what Dr. Wahl has been pleased so happily to term "The Julien System of Electrical Transmission." I feel somewhat diffident in presenting this subject as I am not an electrician. But electricity is approaching so close to the domain of chemistry, that the border line is becoming more and more indistinct, and it is a question now, whether electricity will absorb chemistry or chemistry devour electricity. This, then, must be taken as my excuse. But I am here to-night not so much to expatiate on the electric qualities and attributes of storage batteries, as to inform you that a new field of industrial development in the mechanic arts has been opened. A field that will give employment to thousands of men and women and, therefore, it has a high industrial as well as scientific value. In taking up the theoretical aspect of the case, I would state that I believe a conscientious study of the galvanic battery, and more particularly the storage battery, will help us materially in forming a correct scientific conception of the nature of electricity. We are in the same relative position to-night in regard to electricity that our forefathers were 100 years ago in regard to heat. Not quite so bad, perhaps, for while we are willing to admit that we know nothing about electricity, they thought they knew a good deal about heat.

It was not until Lavoisier's time that a true conception (on a chemical basis) of the phenomena of heat was found, and it is to chemistry again that we must look for a true explanation of the phenomena of electricity.

As it is a fundamental maxim that we can create neither matter nor force, and as heat is the sensible result of chemical union or combination, where does this energy come from? manifestly from the atoms taking part in the reaction.

May not electricity, under certain conditions, be the result of chemical disunion, decomposition or molecular transposition. Of course, we understand that an amount of energy must be absorbed by chemical decomposition equivalent to that developed by chemical combination. But in the galvanic battery, there is a double action of combination and decomposition, in which the energy does not appear and disappear as heat, but under such conditions manifests itself as an electrical current. In other words, *electricity is the mechanical expression of chemical affinity, or the force of chemical attraction.* I mean by that, that the mysterious force that holds an atom of H to an atom of O will, when those two atoms are separated under certain conditions, manifest itself in the form of an electric current, and that the amount of current developed will be directly proportional to the number of atoms involved in the reaction and the intensity of the current, or E. M. F., to the chemical affinity they may have for each other. If such an explanation is correct, it accounts for the lack of progress Mr. Edison has made in the great problem of converting the latent energy in coal into electricity directly without the intermediate stage of steam. Such an explanation might account for the dual nature of electricity, since two different elements must always be concerned in its production. And electricity, derived from the dynamo, might be compared to heat developed by friction.

That this idea of the chemical basis of electricity, if I may be permitted to so term it, is becoming more and more general, is evidenced by the works of Favre and Silbermann, Andrews, Thomson, Bertholet and others, and Mr. John T. Sprague, in his great work on *Electricity*, has done for it what Joule did for heat. The mechanical equivalent of electricity is now as well-known as that of heat, and the day is not far distant when we will have with the table of atomic weights a table of atomic energies, and we can then deal with the mechanical equivalent of energy of a chemical reaction, as we now do with the masses of matter taking part in it.

But to return to our subject.

The Julien Electric Company has been organized for the introduction and sale of storage batteries and systems of electric traction of E. Julien, who, in these departments of electricity, has attained a high degree of perfection. Their successful use at Antwerp, Brussels, Hamburg, and Paris, have warranted their introduction

here. Electricity, like water and gas, ought to be stored, the better to admit of its use at all times and as it may be required. Indeed, it is owing to the want of a proper method of storage that it is not in more general use.

The importance of having a practically, indestructible, secondary battery cannot be overestimated. The flexibility of electricity, so to speak, the infinite variety of purposes for which it can be employed, render a safe, cheap, and simple mode of application—a desideratum of the highest importance. These three elements are united in a storage battery.

History.—The reverse current arising from plates of the same metal, which had been used in a voltameter, was first observed by a French chemist, named Gautherot, in 1801. It was at first thought that the plates received a charge of electricity, and that the secondary pile was, in fact, analogous to a condenser. But the chemists soon demolished this idea, and showed that the return current and counter E. M. F. were not due to a storage of electricity, but to the chemical affinities of substances produced by the previous decomposition. In 1859, Gaston Planté, who made the most exhaustive researches in secondary batteries, constructed a secondary pile, which is really the parent of all modern accumulators. A number of attempts have been made since that time to store the electric energy of a dynamo, the most notable of which are those of Messrs. Houston & Thomson, in 1879, who proposed to use a gravity form of the Daniell cell. Mr. Brush, of electric light fame, and M. Faure.

Under the action of a primary current, the storage battery becomes a reservoir of dynamic energy, which it returns at will, in the form of heat, light, power, etc.

All lead-plate batteries are founded on the principle of Planté's invention, an electrode, consisting of a conducting support with active material. But on account of this very principle, based as it is upon the oxidation of the support plates (which oxidation cannot be arrested), the plates rapidly deteriorate, and are therefore of very little industrial value. Notwithstanding the improvements made upon Planté's secondary pile during the last five or six years, by a large number of electricians, Faure, Brush, etc., the storage battery (which made no little noise at the time the electric light-

ing began to take on the development it has since acquired), did not respond to the public expectation then created, and soon fell into what may very appropriately be called a state of "innocuous desuetude." This condition of things was brought about by the well recognized defects of those batteries—low efficiency—irregular discharge—rapid deterioration—exorbitant cost of maintenance, etc. These are all defects resulting from the application of a principle which has for its basis, as well as consequence, the peroxidation of the positive support plates, whether the active matter on the plates be obtained by disintegration or addition. It remained for Edmund Julien, a Belgian engineer, who first introduced the Faure battery into notice, and who better than any other person became acquainted with its defects, to solve this important difficulty by adopting a principle diametrically opposite to the one employed by his predecessor. His batteries are made according to a new process, that of an *inoxidizable* support plate. They are absolutely exempt from the defects inherent in all other secondary batteries, and so have the industrial advantages which are wanting in all others. It is largely owing to the wide-spread attention which Mr. Julien's invention has attracted, that storage batteries have re-entered the domain of electrical industry, and a new industry of gigantic magnitude will undoubtedly be added to our other resources. In support of this statement, we cite the following facts:

(I.) It is by subjecting his invention to public tests and inspection that Mr. Julien has re-conquered the ground that had been lost. In 1885, on the occasion of the general Exposition at Antwerp, the Belgian government invited the various nations to a trial of the different systems of street-car traction. The contest was begun on the first of May, and lasted until October 31st. "L'Electrique," a Brussels company, organized for the purpose of exploiting Mr. Julien's system abroad, took part in that exhibition, with an electric street car, whose motor was driven by storage batteries. This car, which was operated side by side with cars propelled by steam and compressed air, took first prize and the DIPLOMA OF HONOR, at the same time the jury awarded Mr. Julien a second diploma of honor for his batteries. These were the highest distinctions awarded at the exhibition. The jury which awarded these diplomas consisted of ten members, appointed by the governments

of France, England, Germany and Belgium. In reporting on Mr. Julien's car, they speak as follows:

"The electric street car very regularly performed the ordinary service with one or two cars, and the extra service, also with one or two cars, which was imposed on it.

"The two batteries of accumulators, which were employed, and which seemed to have been *in use previous to the opening of the exhibition, showed no change* when they were withdrawn from service. The metal of the support plates was found to be *absolutely sound*, and the active matter adherent throughout; no plate showed any tendency to buckling or deterioration; this result is to be attributed to the *special composition* of the support plates made by 'L'Electrique.' There was an entire absence of polarization. The treatment of the batteries was confined to the replacing of acidulated water lost by evaporation, and during the charging. The battery weighed less than a ton, including boxes and liquid."

Those acquainted with the work required of a battery employed for traction, and which is peculiarly trying by reason of the heavy currents exacted from plates of the lightest admissible weight, and of the constant shaking of the car, will comprehend the importance of a report like the one above given. An account of the daily work done by the car may be found in the table annexed to the report of the jury. This table shows that the batteries furnished the necessary current during fifteen hours to propel the electric car, drawing another ordinary street car, both heavily laden with passengers, over a course of fifty-nine miles a day.

(II.) In his work on *Electro-Technology*, Prof. Eric Gerard, of the University of Liège, says: "In all storage batteries it has been found necessary to replace the positive electrodes after a certain duration of service, for the reason that the lead becomes transformed into peroxide, and the plates fall to pieces. Mr. Julien, of Brussels, has succeeded in prolonging the life of these electrodes by employing for their support a metallic compound, which prevents their oxidation and buckling."

The author then gives the result of trials made at the University of Liège, in 1885, with a battery of twenty-four elements of the Julien system. This trial was made under the supervision of the International Commission, charged with testing the products exhibited at the Antwerp Exhibition.

The following are the results, already published in the *Electrical World*, of New York, of November 20, 1886.

Duration of charge, ...	7 hours, 33 minutes.
E. M. F. per cell, ...	2·35 volts.
Average strength of current per kilogramme, .	1·86 ampères.
Energy absorbed per kilogramme, ...	10,700 kilogrammetres.
Ampère hours per kilogramme, ...	14.
Duration of discharge, ...	6·48 minutes.
Final E. M. F. per cell, ...	1·89 volts.
Average strength of discharge per kilogramme,	1·74 ampères.
Energy given out per kilogramme, ...	8,600 kilogrammetres.
Ampère hours per kilogramme, ...	11·83.
Commercial efficiency, ...	80 per cent.

On the subject of the capacity of the accumulators and their efficiency, Mr. Gerard states that to store one electrical horse-power hour (270,000 kilogrammetres), it requires 180 kilogrammes of Planté's accumulators; sixty kilogrammes of Faure accumulators, with an efficiency of only fifty per cent., according to experiments made at the "Conservatoire des Arts et Metiers," in Paris.

According to the above results, $\frac{270,000}{10,700}$, or twenty-five kilogrammes of Mr. Julien's accumulators, will give one electric horsepower hour with an efficiency of eighty per cent.

(III.) The diagram (exhibited) of discharge of a Julien battery, composed of twenty-nine elements of forty kilogrammes each, used by the Edison Company, in Paris, shows the efficiency and the regularity of action of the same, charged at a rate of fifteen ampére hours per kilogramme and discharged at a rate of thirteen and one-half ampéres with an efficiency in ampéres of ninety per cent. It will be perceived that the electro-motive force of the battery was two volts, after twenty-two hours of continual discharge.

(IV.) As an additional proof, we would state that Mr. Huber, engineer, who exploits the Julien system (accumulators and electric traction), in Hamburg, has run electric cars in regular daily service of sixty-nine kilometres in the streets of that city, since May, 1886, with a success that all scientific papers abroad are pleased to acknowledge. The same set of batteries has been employed from the beginning without any change or deterioration whatsoever.

(V.) And finally, Mr. Julien has lately been the recipient of new

distinctions in addition to those already obtained by him for his batteries.

On the occasion of the International Exhibition of Arts and Sciences in Paris, which began on June 21, 1886, Mr. Julien decided to renew, on the large thoroughfares of that capital, the official demonstrations made by him at Antwerp. Two of his cars conveyed passengers from the Place de la Concorde to the Palais de l'Industrie during the exhibition.

The jury, presided over by M. Fontaine, President of the International Society of Electricians of France, and composed of ten eminent members of that society, awarded Mr. Julien the FIRST PRIZE and DIPLOMA OF HONOR, for his accumulators and with an equal distinction for his system of electric traction.

His competitors, who exhibited the Planté and Faure types of accumulators, only obtained third-class prizes.

The confirmation of the decision of the Antwerp jury by the Paris jury is of manifest importance.

(VI.) I purposely abstain from citing other than those which, like the preceding, are publicly known and supported by official proof. These facts are sufficient to establish, beyond question, the superiority of the accumulators of this company.

By way of comparison between the Julien and other well recognized secondary batteries—those of Faure, for example—let us turn to a pamphlet, recently issued by the Electrical Accumulator Company (by some called the Vail Company), in which we find the following data in relation to their accumulators:

For a cell weighing 125 pounds, E. M. F., . . .	2 volts.
Intensity of current, ...	35 ampères.
Capacity, ...	350 ampère-hours.

or, a current of $\frac{28}{100}$ ampère and a capacity of $2\frac{8}{10}$ ampère-hours per pound.

It is fair to assume that this is the very best that that battery will do. We have no proof, other than the company's own statement, that it will even do that.

Now, putting these figures side by side with those of the Julien accumulator, given above, and as the result of public and official tests, we find:

	INTENSITY OF CURRENT PER POUND—	
	Faure.	*Julien.*
Ampères per pound, ...	0·28	0·86
Capacity per pound in ampère-hours, ...	2·8	5·38

Thus, the capacity per pound of the Julien accumulator is about *twice as great* as that of the Electrical Accumulator Company's, while the current is *three times more intense*, and with a *greater E. M. F.*

The Brush Company claim only an E. M. F. of 1·82 volts.

These comparisons must not be regarded in the light of criticism. They are introduced solely to show the superiority of the principle of construction of the accumulators of this company, viz : an inoxidizable support plate.

The accumulators of this company may be employed for the following purposes :

The electric traction of all vehicles, more especially street cars.

The utilization of natural forces, such as water-falls and streams.

Domestic lighting.

Running motors of every kind.

Lighting of railroad cars and of street cars.

Aërial navigation.

Medical uses, etc.

I would call attention to the fact that the batteries in use here this evening have been made in this country by men who, six months ago, had never seen or heard of a secondary battery.

They have been brought from our factory in Camden already charged, in trays similar to those used in our system of lighting railway cars. The four trays, containing twelve cells each, will run twenty sixteen-candle-power lamps for eight hours, and you will observe that the lecture-room has been brilliantly illuminated during the evening (three hours) by eighteen sixteen-candle-power lamps and two 150-candle-power lamps, without the slightest diminution in quality or steadiness of the light. The latent energy these forty-eight batteries possess is equal to about 50,000,000 foot-pounds.

BOOK NOTICES.

PETROLEUM, ITS PRODUCTION AND USE. By Boverton Redwood, F.C.S. *Van Nostrand's Science Series, No. 92.* New York, 1887.

Van Nostrand has republished, in convenient 18mo form, as one of his Science Series, an abridgment of the lectures on this subject, delivered last year before the Society of Arts, London, by Boverton Redwood, chemist to the London Petroleum Association.

While the little manual so produced does not cover the wide range of petroleum interests as fully as *Crew's Treatise on Petroleum*, just issued, it gives a correct and very readable account of the occurrence of both American and Russian petroleum, both of which fields have been personally visited by the author. It also gives a very clear presentation of the chemical composition of petroleum, and the products obtained by its distillation. The methods of pipe-line transportation in this country, and of steamer transportation on the Black Sea and the Volga, are also very fully described. Of special value the description are of the several forms of testing apparatus, both open and closed cup, for determing flash and fire test. The construction and method of operating the Abel apparatus, which is the one officially used in both England and Germany, are quite fully treated of.

Quite a section is devoted to a discussion of petroleum lamps, and the relative advantages of different forms of wicks, both flat and round. The comparative merits of American and Russian refined oils, in respect to illuminating value, are also fully stated.

Indeed, both the chemist and the oil dealer, or expert, will find very much of value, while for the general reader the whole subject is stated in a thoroughly interesting way. We can commend it as one of the very best of manuals on petroleum and mineral oils. S. P. S.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1886–87.

THE increased attendance during the year, and the earnest purpose shown by most of the students, are gratifying signs of a public appreciation of the importance of a knowledge of drawing, and also of the efficiency and standing of this school. Machinists, pattern-makers and skilled men connected with engineering trades, are alive to the fact that a thorough knowledge of constructive drawing is essential to their success; but carpenters, masons, plumbers and those connected with the building trades, seem content, as a rule, to blunder along in their rule-of-thumb fashion, cutting, trying, altering and patching, until finally an approximation to a design has to be accepted from sheer necessity. It is to be hoped that the facilities offered to the rising generation to obtain a knowledge of exact methods of laying out work beforehand, will

soon have its effect in improving this state of affairs. Continued effort should be made to educate everyone connected with the various constructive trades up to a realization of the importance of training the imagination and reasoning power, in order to acquire the ability to provide for the harmonious arrangement of all the details of construction, so as to avoid the absurd blunders which are continually occurring and to secure united effort, where one set of mechanics will not disfigure work already done, nor interfere with work to be subsequently done. Let any intelligent person watch carefully the building of a house, for instance, and it will be safe to predict that his admiration of the intelligence of our skilled mechanics will not be greatly exalted. Walls are built up solid and then holes are knocked in them for drain pipes, gas pipes, water pipes, cold-air flues, etc.; joists are laid and then cut to allow passage of hot-air pipes; gas and water pipes are laid without any regard to their interference with other details, or to facility of reaching them for repairs, and, if the outlets are located within a foot of their designated places, it is cause for great rejoicing; and if some are not occasionally covered up by the plasterer and lost, it is because there is a watchful eye around; soil and ventilating pipes are run through the roof after it is slated; closets and niches carefully designed, of specific sizes for special purposes, vary sufficient to ruin the intention, and so on, *ad infinitum.* This condition of affairs is probably responsible for the superficial character and lack of proper detail and definite dimensions in the working drawings of many of our architects who have, doubtless, been so completely disheartened by their experience of the manner in which the constructive features of their plans have been carried out, that they have finally adopted the system of merely suggesting, in a general way, by means of their drawings, and trusting to providence and the builder for the result. The only remedy for all this is the better education of our skilled mechanics, and a very important part of this education should be constructive drawing; for, setting aside the utility of the art itself, its study tends to develop the very qualities that are now lacking, and to prove the ease and accuracy with which the unity of a design and the proper arrangement of all its details can be fully laid down beforehand.

As regards the decorative and artistic branches of drawing, little need be said, as interest in them has been fully awakened, and the good effect of the fostering care which they have received, is shown in the marked improvement in design, displayed of late, in furniture, wall paper, carpets, china, and all our material surroundings. Manufacturers have found that ugly, ungraceful objects will not attract purchasers except at low prices, while artistic effect and handsome decoration command their own reward.

This school has received several improvements this season, the most important of which has been the introduction of incandescent electric lights in the class rooms, adding much to their comfort and healthfulness, and permitting the use of color correctly. As a consequence, some good work has been done in oil painting from still-life, in addition to the studies from casts, in black and white, to which, being an evening school, it has been necessarily confined heretofore. The classes in mechanical or constructive drawing have well maintained their high standard, and the architectural class is

becoming a very important feature. The general system and methods are being steadily improved, and the efficiency of the school increased. Eight separate classes have been taught throughout the season.

The following students are entitled to HONORABLE MENTION:

IN THE SENIOR MECHANICAL CLASS.

T. Edward Schiedt, George J. Henninger,
Robert D. Milner, A. E. Atkinson,
Edward Hein.

IN THE INTERMEDIATE MECHANICAL CLASSES.

George S. Cullen, George F. Johnson, M.D.
G. W. Blackburn, George W. Haldeman,
George W. Irons, Horace E. Jones.

IN THE JUNIOR MECHANICAL CLASSES.

E. W. Davis, Wm. J. Lawrence,
C. P. Barnett, Maurice Patterson,
George R. Moore, Jr., Wm. Bartholomew, Jr.

IN THE ARCHITECTURAL CLASS.

Horace T. Hatton, Walter L. Allen,
Gilbert B. Downes, Stanley Bevan,
William Wrifford.

IN THE FREE-HAND CLASS.

M. Stratton, Jr., Joseph B. Carney,
Arthur Taylor, Wm. H. C. Swain.

IN THE OIL-PAINTING CLASS.

Eugene Dillon, Mary H. Goudkop.

The following students are awarded SCHOLARSHIPS from the B. H. BARTOL fund, entitling them to tickets for the next term, beginning SEPTEMBER 27th:

Vincent A. Clarke, Senior Mechanical Class,
David Uhle, Intermediate Mechanical Class.
Juan S. Kutz, Junior Mechanical Class.
Henry J. Parrott, Architectural Class.
Edward Winkens, Free-Hand Class.
Edwin S. Sutch, Jr., Oil Painting Class.

The following students having attended a full course of four terms, with satisfactory results, are awarded certificates to that effect:

T. Edward Schiedt, Henry J. Parrott,
Robert D. Milner, Horace T. Hatton,
Charles Eggert, William Wrifford,
George A. Baré, Walter L. Allen,
Edward A. Muir, Thomas Stephen,

William E. Mullen,	Edward Winkens,
Edward Hein,	Joseph B. Carney,
Edward B. Seiberlick,	Wm. H. C. Swain,
Mary H. Goudkop,	Eugene Dillon.

In conclusion, it may be stated that no pains will be spared to promote the continued improvement of the FRANKLIN INSTITUTE Drawing School.

WILLIAM H. THORNE, *Director.*

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, May 18, 1887.*]

HALL OF THE INSTITUTE, May 18, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, eighty-seven members and six visitors.

New members added since last meeting, eleven.

The Special Committee appointed to investigate the protest of POUL LA COUR, of Copenhagen, against the award of the Elliot Cresson Medal to PATRICK B. DELANY, of New York, for his System of Synchronous Multiplex Telegraphy, presented a report, which was adopted and referred to the Committee on Publications. The committee's conclusion was, that it found no good reason for revoking the award of the medal which had been granted by the INSTITUTE to MR. DELANY. The committee was discharged from further consideration of the subject.

The Secretary, on behalf of the Special Committee on the establishment of a "State Weather Service," made an oral report, announcing the fact that the bill promoted by the committee, in the Legislature, had passed finally, and had received the Governor's signature. The Special Committee was continued.

Mr. R. MEADE BACHE, of Philadelphia, read the paper of the evening, descriptive of his invention of a "Safety-Stove for Railway Cars."

The Secretary's Report embraced a detailed comparison of the British and American iron and steel trades.

Adjourned. WM. H. WAHL, *Secretary.*

CORRESPONDENCE.

Is ELECTRICITY FORCE or MATTER?

Editors of THE FRANKLIN INSTITUTE JOURNAL:

Dear Sirs:—During the past few years, I have advanced the following argument to a number of electricians, and, having failed to find anyone who can adduce any good argument against it, I thought it might be of sufficient interest to be discussed in your journal. Possibly it may not be new, but I have never seen it published elsewhere.

I believe it is conceded that everything in the universe is either force or matter; therefore, electricity must be one or the other. If it is matter, it must remain the same in amount, and can never be consumed or generated. If it is force, it may be generated by the expenditure of another force—as that in the energy of a steam engine—and will then *grow less in amount* as it is again converted into other forces—as in the energy of motors, lamps, or in heating wires. Now, it is a well-known fact that quantity of electricity measured in coulombs, never is generated, never is consumed, and never does grow less in the circuit, barring leakage. The current flowing out of a lamp is exactly the same in quantity as that flowing into it, the same being true of motors and of generators, showing that electricity itself is neither consumed while doing work, nor is it generated; after doing work in a lamp or motor, it comes out in precisely the same quantity as it entered. Connect only one pole of a battery to a circuit and there will be no current. Why? The battery is not able to *generate* quantity, or coulombs, of electricity; all it is able to do is to take the quantity which flows in at the negative pole and to send it out at the positive pole, with an increased *pressure* or electro-motive force. The battery, therefore, does not generate electricity, but merely raises the pressure of that which flows in. Electricity, therefore, appears to be matter, but not force. It is precisely analogous to water in a water circuit. The water is neither consumed nor generated. The pump merely increases the pressure of the water which flows in at one end; the water motor or turbine consumes this pressure again, converting it into mechanical work of another kind; it does not consume the water. The quantity of water measured in units of quantity, is the same in all parts of the same closed circuit of water, just as the quantity of electricity in an electric circuit. The work which an electric current can do is due to the pressure or electro-motive force; without pressure it can do no work. The electricity in the earth is like the water in the ocean—neither can do work unless raised to some pressure or height, or allowed to fall below its normal level.

The term force is used here as distinguished from energy, as the latter term might be construed to include in it the conception of matter. But even if matter and energy constitute the universe, the above argument applies equally well. It is understood, of course, that by the term *electricity* as measured in coulombs, is not meant *electrical energy* as expressed in watts or joules, for it is beyond question that the latter is energy.

Perhaps it will be found, at some future time, as has been already suggested, that electricity is the ether (which is believed to be matter) whose wave motions are light, and which, in some other form of motion, is an electric current. Perhaps a current of electricity is the bodily conveyance of ether, as distinguished from a wave motion, which is energy in the form of light. In that case, I would suggest that perhaps the relative motion of the ether of space, and the revolving earth may explain the cause of the earth's magnetism, the ether in motion around the earth (relatively) being an electric current producing magnetic effects. The magnetic polarity and direction at the equator are in accordance with such a theory, and the fact that the lines of force bend down into the earth at the magnetic poles may be explained by the well-known fact that lines of force are continuous circuits; they must return somewhere, and they select the axis of the earth, as there is no motion there to develop a counter-magnetism. They cannot return outside of the earth, as lines of force cannot intersect each other, and, in order to return outside of the earth, they would have to intersect. Furthermore, observations show that they do not return outside of the earth.

The only plausible arguments which I can find against the theory that electricity is matter, are that it may be a combination of force and matter, as, for instance, a wave motion; or, it may be, that the real current is in the *same* direction in both wires leading from a machine, therefore emanating from the machine, and, consequently, being force or energy.

Yours very truly, CARL HERING.

Philadelphia, April 18, 1887.

SCIENTIFIC NOTES AND COMMENTS.

ASTRONOMY AND PHYSICS.

THE OBSERVATORY OF MEUDON.—M. Janssen (*Comptes Rendus*, **104**, 1,067), as President of the Academy of Sciences at its meeting, April 18th, gave cordial welcome to the members of the International Conference of celestial photography, and in so doing invited attention to the observatory at Meudon. Regarded as a "vote of confidence" for the new astronomy, the extraordinary equipments now being put up at this observatory are in the highest degree expressive. As is well known, the instruments for the photographic study of the sun here long in use, have been specially adapted to the work, and by the ingenious methods of M. Janssen, have added not a little to our knowledge.

But now colossal additions are to be made. A reflector of 1 metre in diameter and of only about 3 metres focal length, and consequently giving abundant light to images of sensible size, is provided for the optical, spectroscopic or photographic study of faint nebulæ, comets, etc. The mirror, already completed by the MM. Henry, is considered of rare perfection.

As equatorial, the observatory is to have a huge twin instrument, one refractor of $0^{m}{\cdot}81$ (32 in.) aperture, to be devoted to spectroscopy and the ordinary

work of astronomy, the other of $0^m \cdot 62$ (25 in.) aperture, intended for photography; the former to serve as a finder while an exposure is made in the latter. The optical portion of the instrument is the work of MM. Henry, the mechanical of M. Gautier. One can appreciate the interest an instrument like this, with a photographic refractor of from 53 to 56 feet focal length, will possess for photography of the moon, double stars and clusters.

But a special interest attaches to this observatory on account of the appliances provided for the study of gases and vapors under great pressures. The laboratory, 350 feet in length, is provided with a series of tubes capable of sustaining high pressures, also with the optical appliances necessary for the study of absorption spectra. M. Janssen mentions one isolated result of work in this direction, to show the interest that attaches to such researches for astronomy.

The study of oxygen shows two orders of phenomena of absorption, the second system consisting of dark bands which are developed according to the square of the density of the gas. An important consequence of this law, of the square of the density then is that, a nebula of a diameter of ten times that of the earth's orbit, and containing oxygen at a low density, might be traversed by rays of light, without presenting the bands of this gas, and that consequently we should be very reserved in concluding the absence of a gas or vapor from a celestial body from the appearances alone of its spectrum. M. B. S.

Recognition of American Astronomy.—Mr. J. W. L. Glashier's address (*M. N. R. A. S.*, **47**, 203), on presenting the Gold Medal of the Royal Astronomical Society, reminds us that this is the second successive year in which an American astronomer has shared the honor of receiving this medal. Last year, it was awarded conjointly to Prof. Edward C. Pickering, Director of the Harvard College Observatory, U. S., and the Rev. Charles Pritchard, D.D., Savilian Professor of Astronomy in the University of Oxford, for their "Photometric Researches." Unaware of Prof. Pickering's comprehensive plan, Mr. Pritchard had also taken up the subject on a large and successful scale, and hence the joint medal, upon the award of which the President took occasion to designate Prof. Pickering's photometry as a "magnificent contribution to stellar astronomy, with which his name will in future be honorably associated."

This year, Mr. George William Hill, of the *Nautical Almanac* office, at Washington, receives the Gold Medal of the Society for his researches upon the Lunar Theory. On account not only of the astronomical, but also of the distinctive and elegant analytical methods employed. Mr. Glashier is justified in giving the unusually detailed review in his President's address, and which consequently becomes an interesting *résumé* of the present condition of the theory. Among the numerous and important additional investigations of Mr. Hill mentioned, are those on the motions of Jupiter and Saturn, upon which he has already been engaged for nine years, and which will probably require three or four years more for their completion. These investigations will displace those of Leverier, which now, in the case of Saturn, fail to represent adequately the observations, and, to use the words of Mr. Glashier, will

constitute "the largest and most complete investigation of the kind that has yet been performed on the American Continent." M. B. S.

Photographic Search for a Minor Planet.—Mr. Isaac Roberts (*M. N. R. A. S.* **47,** 265,) communicates an account of the successful photography of the minor planet Sappho. Scarcely any observations of this planet had been published since 1872, and hence Mr. Bryant, who is engaged in determining its orbit, appealed to Mr. Roberts to find the planet if possible by photography. The planet is, however, not only of the eleventh magnitude in brightness, but its motion in an hour is equal to about 4·2 times its photographic diameter, and thus the trail left not exceeding in density that of a thirteenth magnitude star. With an exposure of one hour on December 30th, the trail of the planet was distinctly recognized and the error of the ephemeris deduced from the photographs is in close agreement with several meridian observations made about the same time at Duerecht.

This is probably the first instance in which photography has been successfully applied for this purpose. It is a distinct demonstration that asteroids of the eleventh magnitude leave strong trails on the photographic plates, and indicates that under favorable conditions those down to the thirteenth or fourteenth magnitudes may be photographed. Another inference suggested by Mr. Roberts is that one astronomer could, in about three years' time, photographically discover all the asteroids existing down to the fourteenth magnitude. M. B. S.

Solar Statistics and Terrestrial Magnetism.—R. Wolf, (*Astron. Nach.*, **116**, 259), of Zürich, in tabulating side by side the relative number of sun spots, r, and the variation of the magnetic declination at Milan, v, for each month of the year 1886, shows that both were decidedly less than in the previous year. He finds the mean value for r 25·7, for v, $6'·75$, and inserting this value for r in the formula derived by him some years ago for Milan:

$$v = 5'·62 + 0'·045 . r$$

the resulting value for v is $6'·79$. This value differing but $\frac{7}{100}$ from the observed value again confirms the remarkable relation between the two phenomena—a relation which the Zürich astronomer was, we believe, the first to announce. M. B. S.

New Double Stars.—Prof. G. W. Hough (*Astron. Nach.*, **116,** 274), publishes a catalogue of 209 new double stars discovered by him with the eighteen and one-half inch refractor of the Dearborn Observatory at Chicago. Only thirty-nine of these have a distance of more than $5''$, and these with few exceptions are excessively unequal in magnitude; seventy-seven have a distance of $2''$ to $5''$; forty-three, $1''$ to $2''$; twenty-five, $0''·5$ to $1''$, and twenty-five, $0''·5$ and less. These double stars are for the most part difficult objects even with the Chicago telescope, and it is certainly creditable to have discovered so many new objects of interest in a field already well explored.

M. B. S.

A New Unit for Absolute Time.—Mr. Lippman (*Comptes Rendus*, **104,** 1,070) proposes a unit of absolutely invariable time, which, as independent of every astronomical hypothesis, would serve as a check on the

universally adopted unit, the second. The proposed unit of time is the specific resistance of mercury in absolute electro-static units. The constancy of this resistance, the fact that it is indifferent what units of length and mass are used, and the high degree of accuracy that the available experimental methods for its determination promise, are cited in its favor in detail.

M. B. S.

Electrical Insulation.—The importance which insulation of wires carrying electrical currents of high potential or great intensity, has acquired, is evidenced by the appointment of a Scientific Commission, composed of Profs. Houston and Marks and Messrs. Hering and Garver, by the National Electric Light Association. The duty imposed upon this commission is to formulate rules and regulations for the proper installation of plants for electric lighting, to investigate the various forms of insulation now commercially used, and to report at the next meeting of the National Association.

This Commission is also directed to meet and confer with a committee appointed by the Electric Club, of New York, and also with a committee of underwriters, with a view to formulating and agreeing upon rules which will be satisfactory to insurance companies.

Fire-proof insulation, which will not take fire from a wire overheated by too intense a current, is, in most instances, not water-proof; and water-proof wire, which will prevent leakage and short circuiting by means of water or moistened wood is, in turn, not fire-proof.

Paraffine insulation takes fire, and carries the flame, like a taper, along the whole length of the wire; it may, however, be regarded as water-proof under ordinary conditions. India-rubber is better, but will burn. The "Underwriters'" insulation will not burn readily, but is not water-proof, and, when exposed to the weather, soon hangs in rags from the wires, the cotton-painted covering having rotted away. Perhaps regular repainting might prevent this, but we do not know that any company has tried the experiment.

Insulation in underground conduits has been suggested, and ardently advocated, as a preventive of danger from electricity, but the danger from leaks in high potential circuits would be very much increased, as a person standing upon the ground and touching only one of the wires (he need not complete the metallic circuit) might receive a fatal shock should there be a leak, and, in order to be used, the wires must come out of the ground somewhere.

The alternating currents of high potential, which it is proposed to use in the Gaulard and Gibbs system of converters (induction coils) can give severe shocks when only one of the wires is touched, and should have special care in insulation, and, although the induction coil is a simplified dynamo, in which the lines of force cut the armature wires, instead of the armature wires cutting the lines of force, as with the dynamos. English experience still shows great danger of fire from overheating of the cores of these coils, due to the rapid reversals of polarity when long continued. This should be overcome before their use is permitted in unguarded places.

The public should demand the most unmistakable proof of proper safeguards against loss of life or by fire, from any new scheme of an electrical nature before permitting reckless inventors to experiment at the risk of life and property.

It has been frequently said that electric lighting has been killed in England by too much legislation, as there they do not permit 200 volts to be exceeded inside of buildings. In America we have no such restrictions, and while we have not killed electric lighting by legislating for the safety of the public, we have directly or indirectly killed a great many people by permitting ignorance, recklessness, and cupidity to take risks which are controllable and unnecessary.

At the inquest upon the bodies of John Johnson and John Gibson, killed at the Temple Theatre fire, it was shown as conclusively as circumstantial evidence could prove it, that the origin of the fire was either a short circuit in a flexible leader to one of the incandescent lamps, or by reason of one of the incandescent lamps being so placed as to be enveloped and have its heat confined by a curtain.

It was further discovered that the whole of the wiring which followed that properly done by the Edison Company, was done by one or more employés of the theatre lessees, in the most reckless and dangerous manner. One of these employés at least was permitted to do most of the work without having the least knowledge of electricity or its laws and dangers.

The jury were careful to say in effect that they regarded incandescent electric lighting as the safest form of artificial lighting in existence, but there is no warrant in this statement for taking risks that no one would dream of taking with gas- or oil-lighting.

The recent inquest, during the past week, upon the body of a lineman of the Brush Electric Light Company, developed the fact that his death resulted from an accidental contact with a poorly-insulated wire. It was hardly chargeable to carelessness on the part of the company, perhaps not to carelessness on his part. However, the fact remains, that, had the insulation been good the man might now be alive.

The question arises, What shall we do to protect ourselves? Legislation quite frequently does more harm than good, because it cannot keep pace with the progress of scientific discovery, and places unnecessary limitations upon enterprises worthy of encouragement.

Can we prevent, or, at least control, risks to life and property? The underwriters and the responsible companies engaged in electric lighting are endeavoring to do this by the appointment of commissions composed of men known to be familiar with the laws of electricity, who shall devise means to avoid risks of fire.

Should not our state or our municipal government appoint similar commissions, charged to supervise means to avoid risk to our lives, and demand that all companies shall prove to this commission that they have devised proper safeguards against possible *murder* before permitting them to install their plants?

W. D. M.

CHEMISTRY.

Distillation and Purification of Mercury. (*Berl. Ber.*, **20**, 497.) It is generally accepted that mercury cannot be fully purified by distillation, and by earlier observations of the author had found that these distillations left crude mercury quite impure. Some experiments have now been made to ascertain whether the foreign metals are vaporized with the mercury, as water vapor carries over other substances, or whether they are carried off mechanically. The mercury was mixed with lead, bismuth, tin, sodium and copper, and then distilled, first from porcelain, afterwards from glass retorts. As long as the metal is very impure, the glass retorts are destroyed, hence the necessity of distilling first in porcelain. After twelve distillations, the retorts contained no residue, and the mercury was perfectly pure, as was proved by dissolving about two grammes in nitric acid, evaporating in a weighed platinum capsule and igniting; the weight of the capsule was unchanged. W. H. G.

Production of a Dye and Tanning Material from Catechu. E. Ziegler (*Dingler's Polyt. Journal*, **261**, No. 1). From an abstract in *Journal of Soc. of Dyers and Colorists*, **3**, 48.—The process described by the patentee (German patent, No. 36,472), has for its object the separation of the coloring matter contained in catechu from the tanning agent, and thus rendering possible the separate application of both.

The catechu, which generally comes into the market in bales of fifty to 100 kilos, is first broken into small pieces; a given quantity is then put into a suitable vessel, provided with a stirrer, and from two to three times the weight of cold water is added. The tanning material is dissolved in this—more quickly when stirred. The coloring matter insoluble in water, remains behind as a fine powder. As pieces of leaves, insects, and other impurities, are always found in the bulk, these are next separated by filtering through a sieve.

The coloring matter and the tanning agent are now separated by filtration, or by means of a filter press. The coloring matter which remains on the filter in the form of a powder, may be used at once for dyeing; but it is better to boil it up with a little water, when it dissolves, and then to dry it by heating with steam. A cake is the result.

It is said to be advantageous to add mordants, such as alum or tartar, in given proportions, before steaming. The cake, obtained after steaming and drying, is then powdered, and can be used for dyeing in exactly the same manner as catechu. The new coloring matter is said to yield considerably better than catechu, and to give better and purer shades.

The tanning material is best introduced into commerce after evaporation to the consistency of a syrup. By mixing it with a small percentage of nitric acid, its color is clearer. It forms a very valuable and powerful tanning agent—one part replacing about ten parts of the best oak bark—it acts very quickly, and is applicable for tanning of upper or sole leather, reducing the time of the operation considerably, without damaging the leather.

It is self-evident that in preparing the catechu, on account of the tanning material present, the use of iron apparatus must be avoided. H. T.

Determination of Phosphorus in Iron and Steel.—Leopold Schneider (*Dingler's Polyt. Jrl.*, **263**, 383) communicates his results on the analytic determination of phosphorus in iron and steel, and on its state of combination in the latter. The author shows, by a series of analyses made with a metal containing iron = 78·6, phosphorus 14·6, that considerable quantities of the latter may escape detection unless the proper precautions be taken.

Of the above metal he digested one gram with 15 cc. of nitric acid (spec. gr. 1·2) for twenty-four hours on a water-bath, let it evaporate to syrup consistency, and took it up with hydrochloric acid and water. From this solution the iron was removed by $(NH_4)^2 S$; it was then evaporated several times with HCl to destroy the nitrates, and PH^3O^4 was precipitated as $(Mg,NH_4)PO^4$. The precipitate corresponded to 13·32 of phosphorus. From the filtrate NH^3 was expelled by boiling, acidulated slightly with HCl and $HgCl^2$ added. After some rest 0·099 gr. $Hg_2\,Cl_2$ was precipitated. This was filtered off, and from the filtrate, after removing the mercury by hydrogen sulphide, magnesium solution precipitated 1·23 per cent. of phosphorus, which, added to the amount found first, is equal to 14·55. The author has thus shown that some phosphorus, in pig iron or steel, will only be oxidized to phosphorous acid, by nitric acid, unless the solution be evaporated to *dryness* and then heated until the *ferric nitrate begins to decompose.*

In order to determine the state of combination of phosphorus, the author separated the iron phosphide from different samples of pig iron, by means of an aqueous solution of cupric chloride. This solution dissolves readily the free iron, the carbide, but not the phosphide. The pig iron and the residuum were analyzed separately. Results are in the following table:

	Pig Iron.							Residuum.	
	C	Graphite.	P	Si	Mn	S	Cn	P	Mn
Spiegel iron,	3·3	. .	2·5	0·06	0·2	0·04	. .	18·6	. .
White iron,	. .	. .	1·45	. .	. .	. .	. .	18·6	. .
White iron.	3·56	. .	0·53	0·07	2·47	0·028	0·03	18·2	. .
Gray iron (coarse),	. .	2·2	1·48	4·0	. .	. .	. .	18·2	. .
Gray iron,	0·55	2·85	0·94	1·8	0·07	0·01	0·01	18·5	. .
White spiegel iron,	. .	. .	2·01	0·46	4·33	. .	. .	20·5	5·7
White spiegel iron,	3·98	. .	3·4	0·89	18·15	. .	. .	37·7	52·8
Ferro-manganese,	5·28	. .	0·38	. .	28·7	. .	. .	38·8	54·4

The most striking feature in this table is the constancy in the phosphorus of the residue in all pig irons free from manganese, no matter how much their carbon and silicon percentages may vary. In all of these the residue corresponds to a ferro-phosphide of the formula $Fe_3\,P$. With the manganese the phosphorus in the residue rises rapidly. If the iron percentage be calculated as $Fe_3\,P$, then the manganese corresponds to the formula $Mn_3\,P_2$. The phosphide was invariably obtained as a pulverulent granular admixture. It is not the cause of the characteristic reflecting surfaces in spiegeleisen, because after a piece of this latter had been kept in dilute HCl for several months, it

could be broken into many delicately-thin leaves, from which concentrated acid extracted all the phosphorus without destroying the shape.

The small quantities of phosphorus contained in wrought iron and steel, exists probably as the same phosphide found in pig iron disseminated in granular particles.

The fact that relatively more manganese is found in the residue than in the original pig iron, tends to demonstrate a stronger affinity of phosphorus for manganese than for iron. G. A. K.

General Methods for the Formation of Crystals by Diffusion. By C. E. Guignet (*Comptes Rendus*, **103**, 873).—The methods described by the author are a development of the researches of Becquerel on the slow reactions of fluids through porous substances. When a solid is introduced into a saturated solution of another solid in a menstruum in which the first is soluble, there is a replacement in the solution, and the substance in solution separates in crystals. Sulphur is thus separated from its saturated solution in carbon disulphide by the introduction of solid paraffin. Also by the gradual dilution of the saturated solution through diffusion, the solid separates in crystals; thus a saturated solution of lead chloride in hydrochloric acid covered with a layer of hydrochloric acid, and this by a layer of water, will deposit fine crystals of lead chloride. The preceding actions are physical, but the method is equally applicable to cases in which double decomposition takes place. Crystals of sodium sulphate, placed in a saturated solution of barium chloride retain their form, but become opaque; when they are broken, each is found to be a mass of small crystals of barium sulphate. If both substances be in solution, one of the liquids is placed in a crystallizing dish, and this is set in another deeper dish containing the other solution, both dishes being filled nearly to the top of the inner one. Both vessels are then carefully filled up with water until communication is established. Sodium sulphate and calcium chloride thus give long crystals of calcium sulphate; sodium sulphate and lead acetate yield crystallized lead sulphate; potassium ferrocyanide and lead acetate give long, pale yellow needles of lead ferrocyanide. W. H. G.

Estimation of Aluminium in Presence of a large Proportion of iron. By R. T. Thomson (*Chem. News*, **54**, 252).—In view of the introduction of the mitis alloys, these methods are of practical interest. The first method is best adapted when there is but little manganese present; if there be much manganese, the second method should be used. (1.) Reduce the iron to the ferrous state by passage of sulphur dioxide, boil off the excess of the latter, and when cold add phosphoric acid or ammonium or sodium phosphate in excess of that required to precipitate the alumina, then ammonia until a permanent cloudiness appears; lastly, an excess of ammonium acetate. If the precipitate contain much iron, it should be washed, again dissolved in hydrochloric acid, reduced by sulphur dioxide and the whole process repeated. (2.) The iron solution is reduced as before, ammonia is added until permanent cloudiness is produced, then excess of ammonium acetate, and boil; if the precipitate contains much iron, the operation must be repeated. In either

case, when a satisfactory precipitate is obtained, it is dissolved in hydrochloric acid, a little nitric acid added, and, after boiling, the liquid is nearly neutralized with sodium hydroxide, and then boiled with a large excess of the latter reagent. The aluminium is then precipitated as phosphate, and the precipitate washed with a one per cent. solution of ammonium nitrate containing about one decigram per litre of mono-ammonium phosphate. It is weighed as $Al^2 P^2 O^8$. W. H. G.

SPECTROSCOPICAL TEST OF TAR COLORS.—P. Schoop (*Dingler's Polyt. Journal*, **262**, 424).—Artificial and natural dye stuffs are tested with regard to shade and purity as well as strength, by sample dying, which requires great practice and shows differences in strength of but five per cent. only with difficulty, whilst differences in shade often lead to errors in estimating the strength.

The investigations of H. W. Vogel, K. Vierordt and G. Krüss have rendered it possible to determine, with rapidity and accuracy, the amount of coloring matter in a solution. Their method is based on the following considerations: Every substance can absorb only those rays of light, which have the same rate of vibration as its own molecules, producing, therefore, absorption bands in the spectrum of the light reflected by it. With the same light, the absorption band is the darker the greater the amount of absorbing (colored) substance contained in the unit of space, and there is a simple relation between the absorption of the light and the quantity of coloring matter.

If $\frac{1}{3}$ of the rays of a beam of light pass through a 1 cm. stratum of color solution, a second similar stratum will allow only $\frac{1}{3}$ of this $\frac{1}{3}$ to pass through it, and so on. The same result is obtained if, instead of the light passing through two such strata of solution, it passes through one of double strength. Therefore, if the amount of light which passes through a 1 cm. stratum of a solution, containing 1 mg. of color in 1 l. $= a$, then the amount of light passing through a solution of x-times the concentration of the former is $b = a^x$, where x indicates the number of mg. of coloring matter in 1 l. solution, or $\log b = x \log a$ or $x = \log b \div \log a$. The quantities a and b are easily and rapidly determined by the spectroscope. P. Schoop has adapted Krüss's apparatus for quantitative spectral analysis for practical purposes. The instrument consists of a tube with slit, prism and telescope, which is so arranged that any position in the spectrum can be examined and determined.

The slit is divided in two halves, the upper is movable, the lower is fixed. Immediately in front of the lower slit is placed a vessel with parallel glass sides, 1 cm. apart, to hold the solution of dye stuff to be tested. By regulating the height of the solution in this vessel, two spectra are obtained, one of the source of light (a petroleum lamp) and the other the absorption spectrum of the solution. The darkest part of the latter is then found, and the movable slit regulated until the amount of light in each spectrum is equal. The extent of movement is shown on a drum attached to the micrometer screw, and serves as measure for the intensity of the light, that of the upper slit being the unit. The average of a number of readings, which can be made comfortably within a minute, is put down as the intensity of light.

Having in this manner determined the intensity of light, for a normal solution of a dye stuff, a similar determination at the same position of the spectrum suffices to calculate at once the concentration of a solution to be tested with the aid of the above formula.

Dilution causes no change in the position of the maximal absorption, and the spectrum of a mixture of two color solutions is equal to the sum of the absorption spectra of the single solutions.

The apparatus can also be used to analyze commercial mixtures of two and more colors; also to determine the end of the reaction in the formation of coloring matter (rosaniline by arsenic acid, or nitro-benzol, methyl violet, bluemelts, etc.), also for standardizing colored salt solutions for analytical purposes (permanganate) and for color reactions. O. L.

A VOLTAIC CELL WITH CARBON ELEMENTS AND WITHOUT METAL. By D. Tommasi and Radiguet (*Bul. Soc. Chim.*, **47**, 85).—The positive electrode of this cell is a carbon rod, coated with lead peroxide and enclosed in a canvas cover. This is placed inside a carbon tube pierced with holes, and the whole is surrounded by fragments of gas carbon in a glass jar, which is then half filled with a saturated solution of common salt. The cell gives an electro-motive force between 0·6 and 0·7 volt. It quickly becomes polarized, and is only adapted where an intermittent current is required; its duration is then practically unlimited, and there is no action when the circuit is not closed. The water must be replaced as it evaporates; a small quantity of calcium chloride added to the salt solution will prevent its evaporation. The theory of this couple is as follows: The conversion of one molecule of lead monoxide into the peroxide disengages 12·14 calories; the heat of formation of the monoxide being 51· calories, that of the dioxide must be 63·14 calories. The carbon decomposes water in closed circuit, the reaction being $C + 2\,H^2\,O = CO^2 + 4\,H$, and the thermal effects of this reaction are $102{\cdot}6 - 138 = -35{\cdot}4$ calories. In the canvas sack there is reduction of peroxide and formation of water, according to the equation, $Pb\,O^2 + 4\,H = Pb + 2\,H^2\,O$, the thermal reaction being $138 - 63{\cdot}14 = 74{\cdot}86$ calories. The resultant heat of the two reactions is the algebraic sum of their thermal effects, or $74{\cdot}86 - 35{\cdot}4 = 39{\cdot}46$ calories. If the volt be considered equivalent to 46·3 calories, the electro-motive force of the cell should be $\frac{39{\cdot}46}{46{\cdot}3} = 0{\cdot}85$ volt. With 47·16 calories as the equivalent of the volt, the electro-motive force should be $\frac{39{\cdot}46}{47{\cdot}16} = 0{\cdot}84$ volt. Direct measurements gave between ·6 and ·7 volt, and the difference is to be attributed to the facility with which the cell becomes polarized, and the possible formation of carbon monoxide which would diminish the heat disengaged by the first reaction. W. H. G.

PREPARATION, PROPERTIES AND CONSTITUTION OF INOSITE. By M. Maquenne (*Bul. Soc. Chim.*, **47**, 290; *Comptes Rendus*, **104**, 225).—Inosite has long been regarded as analogous to the glucoses in constitution, and although it has been extracted in small quantity from muscular tissue and from many plants, it had never been obtained in sufficient quantity to permit

of exact investigation. The author has succeeded in obtaining a considerable proportion of it from dried walnut leaves, which yield very nearly three grammes per kilogramme. For the method of extraction, we must refer to the original memoir. The composition of the crystallized substance is $C^6H^{12}O^6$ with two molecules of water, which are lost at 110°. Its chemical properties—the action of reducing and oxidizing agents assign to it the structure $C^6H^6(OH)^6$, and show it to be hexoxyhexhydrobenzene. W. H. G.

FORMATION OF HYDROGEN SILICIDE AS A CLASS EXPERIMENT. By A. Mermet (*Bul. Soc. Chim.*, **47**, 306).—The preparation of pure hydrogen silicide as a class experiment is tedious and difficult. Its spontaneous combustibility may be quickly and easily shown as follows: A piece of magnesium ribbon 2 or 3 centimetres long is introduced into a clean, dry, glass tube, 4 or 5 millimetres in diameter and 5 or 6 centimetres long and closed at one end. It is then heated in the Bunsen flame until a bright incandescence shows that a portion of the silica of the glass has been reduced by the magnesium; the magnesium silicide formed covers the bottom of the tube with a black deposit. Before the tube has become entirely cold, a few drops of hydrochloric acid are introduced. Instantly there is a disengagement of hydrogen mixed with hydrogen silicide, and the bubbles take fire at the mouth of the tube, producing a crackling sound and a white smoke of silica. W. H. G.

HOPEINE. (This JOURNAL, **123**, 419).—The hopeine claimed to have been discovered in wild hops by Williamson, has been shown by Ladenburg (*Berl. Ber.*, **19**, 783,) to be a mixture of morphine with another more soluble base. B. H. Paul (*Pharm. Jour.*, **111**, 877), and C. Lenken (*Chem. Zeitung*, **10**, 553,) have found that the other base is in all probability cocaine. W. H. G.

MELTING POINT OF MAGNESIUM. Victor Meyer (*Berl. Ber.*, **20**, 497).—The text books give (about) 500° as the melting point of magnesium, a temperature which does not agree with the observations of several manufacturers who pointed out the fact to the author. Experiments have shown that when heated in an atmosphere of hydrogen, magnesium melts almost simultaneously with sodium hydroxide, of which the fusing point is 800°. That of magnesium is very little below the latter temperature. W. H. G.

ON THE DESSICATION OF GASES.—J. D. van der Plaats (*Rec. Trav. Chim.* **6**, 45,) has published a review of the literature on the dessicating agents employed for gases, and concludes that sulphuric acid diluted with six or eight per cent. of water is preferable in all cases in which neither absorption nor combination takes place. Special attention is directed to the importance of repeatedly calcining with sulphuric acid the pumice used for gaining absorbing surface in order to decompose chlorides and fluorides, and washing between the calcinations with dilute sulphuric acid. The **U**-tubes employed should be drawn out and bent for connections after the pumice and acid have been introduced, or if a cork be employed it should be on the side by which the gas is introduced, and should be covered with good sealing wax. Caoutchouc tubes used for connections should be dried in the dark over sulphuric acid, and should be thick like those used for filter pumps, in

order to prevent passage of air and water vapor. Absorption tubes should always be weighed open after they have taken the temperature of the balance.

W. H. G.

SILVER IN THE VOLCANIC ASH FROM ERUPTION OF COTOPAXI, ON JULY 22 AND 23, 1885. J. W. Mallet (*Proc. Royal Soc.*, **42**, January 6, 1887).—The author has analyzed the ash collected at Bahia de Caraguez, about 120 miles due west from Cotopaxi, where it fell to the depth of several inches. The specimen was a light brownish-gray, very finely divided, mobile powder, soft to the touch. Quartz, two felspars, augite, magnetite and thin scales of deep-red specular iron ore were distinguished by aid of the microscope. When strongly heated, it turned dark red-brown, and fused to a nearly black slag. "Several concordant experiments proved that silver was present to the extent of about one part in 83,600 of the ash, or about two-fifths of a Troy ounce per ton of 2,240 pounds. Small as is this proportion, it must represent a very large quantity of silver ejected during the eruption, in view of the vast masses of volcanic ash which must have been spread over such an area as is indicated by the fall at so distant a point as Bahia de Caraguez."

W. H. G.

IN A PAPER read before the Photographic Society of Great Britain, Capt. Abney describes a method of determining the density of different portions of a negative, which consists, in brief, in throwing a magnified image of the negative upon a screen, in front of which is a rod which casts a shadow upon it. Any part of the negative can be moved into this part of the field, and at the same time a beam of light, from that employed for projection, is thrown by means of a mirror placed at one side, at a suitable angle, over the patch of light formed on the screen by the lens, throwing another shadow of the rod. The variation of the light from the second source is accomplished by passing it through sectors revolved by a small electro-motor, the aperture of the sectors being capable of measured variation, by which intensities are compared. By rendering the shadow of the rod equal in intensity and reading off the variation in the second source of light, as indicated by the width of sectors employed, the relative densities of the different portions of the negative can be determined as the relative values of the projecting light and comparison light are constant. C. F. H.

AS A MOUNTANT for albumen prints without cockling, upon any kind of paper, Prof. Rood recommends a thick solution of bleached shellac in alcohol as meeting every requirement. C. F. H.

THE ANALYSIS OF COFFEE. L. Pade (*Bul. Soc. Chim.*, **47**, 501).—The Municipal Laboratory of Paris has been engaged in examining the fraudulent manipulation of coffees, the fraud consisting in the manipulation of the green berries, and the moistening of the dried. The densities of the specimens were determined by the aid of a simplified Regnault's volumometer. The extreme densities of unmanipulated and sound specimens:

	Green Coffee.	*Roasted Coffee.*
Maximum,	1,368	635
Minimum,	1,041	505

The densities of green coffees manipulated by partial drying are between the lowest of the green and the highest of the roasted. This manipulation, which is carried on extensively in England and in Holland, is practised as follows: The too-advanced berries are separated from the damaged coffee; the remainder is carefully washed in order to remove the soluble salts derived from the sea water, and then bleached with lime water; it is again washed to remove the lime, and quickly dried in an oven through which passes a current of air. The desired tint is then given by a slight heating, or by dyeing with an orange dye; the latter colors are easily detected by macerating the coffee for a few minutes in alcohol, which dissolves the dye. Green Brazilian coffees are in a similar manner transformed into orange Javas, the profit being about thirty per cent. The densities of coffee treated in this manner in the laboratory were between 899 and 929, and a coffee purchased in the market and found to be colored with β naphthol orange had a density of 939. There is reason to suspect manipulation by partial roasting, when the density of a coffee is below 1,000.

During drying by heat, coffees lose from seventeen to nineteen per cent. of their weight, according to their kind and age. To compensate this loss, the dealers often endeavor to replace the water, but this is only practicable by the condensation of steam in the mass. Twenty per cent. of water may thus be added without the coffee appearing moist, but instead of being hard and crisp between the teeth, the berries are tough and elastic.

Coffee which has been roasted and then moistened loses part of its water on exposure to the air, and to prevent the loss, the grains are often coated with glycerine, palm oil, or even vaseline. The densities of such coffees are higher than those of normal roasted specimens—between 650 and 770. If, however, the roasting has been carried too far, the density may fall to 480, and a normal density may result from moistening.

The quantity of water that has been added to a coffee may be found very exactly by heating to 110° for six hours. Under such circumstances, dried coffees lose only one or two per cent., but such as have been moistened lose in addition the water that has been added. W. H. G.

THE TRANSFORMATIONS EFFECTED IN POTABLE WATER BY THE DEVELOPMENT OF BACTERIA. T. Leone (*Gaz. Chim. Ital.*, **16**, 505).—The author has studied the variations in the quantities of ammonia, nitrates and nitrites, occurring during twenty-two days in the water of Mangfall, in Monaco. His conclusions are that when the development of micro-organisms is considered in all its phases, their action is beneficial and purifying. The double function of oxidizing and reducing with which some bacteria seems to be endowed, is only apparent. Their unique function is to oxidize organic matter and the products of its decomposition. The oxygen, however, is furnished to the oxidizable matters by those substances which will yield it readily, and it is then the nitrates which contribute their portion. The oxygen of the atmosphere is the main agent in the oxidation of ammonia to nitrous and nitric acids, and when the medium in which the bacteria live is inaccessible to the air, the nitrification is retarded. The variations in the quantity of organic matter, and the

extreme variations in the quantities of ammonia, nitrous and nitric acids occasioned by bacteria, is of importance to the hygienist. The fact that in twenty-two days two-thirds of the organic matter was no longer revealed by potassium permanganate, and that the qualities of ammonia, nitrous and nitric acids, varied between zero and a relatively large gravity, shows that estimations of these substances are of value only when made on a water at the time it is delivered for consumption. W. H. G.

MISCELLANEOUS.

Apprenticeship and Professional Teaching.—Printing is among the industries which have the greatest need of being raised and sustained in the quality of labor. What was formerly an art practised by a small number of select workmen, has now become a trade transformed by the requirements of quick production. The multiplication of daily papers, magazines and all classes of printed matter has resulted in a sensible lowering of the standard of workman's skill. Efforts should be redoubled, not only that the artistic production of printing may not be endangered, but that the common, cheap production may not fall below that degree of correctness which every industrial product should maintain. Apprenticeship, as it is now regulated, does not give satisfactory results, sometimes the master fails to do his duty, sometimes the apprentice breaks his engagement as soon as a first degree of education insures his gaining a salary elsewhere. Often it is impossible in one work-shop to train a workman in different branches of the same work, and often the workmen themselves limit the number of apprentices, fearing the influence of their labor on the rate of wages. The French government has tried to remedy this evil by establishing special schools for industrial instruction; still, many capitalists prefer to prepare, under their own direction, recruits for their force of workmen. This plan has been successfully carried out in M. Chaix's professional school for young printers in connection with the central railroad printing-house in France. Applicants must be thirteen years of age, and prove that they have received primary instruction. The term of apprenticeship is four years. Beside practical instruction directed by a foreman for each of the specialties, the apprentice receives ample instruction in history, geography, the ancient and modern languages. Knowledge necessary for him when he may be called upon to work from difficult and incorrect copy containing technical terms or quotations from foreign languages. Outside of the regular courses, there are lectures, distributions of books written for apprentices' use, a library of appropriate works, and many helps also for moral education. Hygienic conditions are assured by frequent medical visits, by a system of warm baths, and even by vacation trips to the mountains or the sea for those in poor health. Especial precautions are taken to prevent risks in the use of machines. The apprentices are taught foresight and saving, and start bank accounts with the percentage which they receive on the result of their labor. By training in dexterity, easy reading of manuscript, judicious use of characters and the intelligent disposition of tables of figures, they are led progressively to do productive work for which they may receive a bounty of from ten to seventy cents a day. After

finishing their course they easily earn from $1 to $1.20 a day.—*Bull. de la Soc. d'Encour., July, 1886.* C.

GRAPHICAL INTERPOLATOR.—In the *Annali della Società degli Ingegneri e degli Architetti Italiani,* Roma, Anno 1, 1886, fasc. iv, a very ingenious device is proposed and described by G. Torricelli, C. E., to divide the distances between level curves or soundings, on charts, in any number of equal parts,

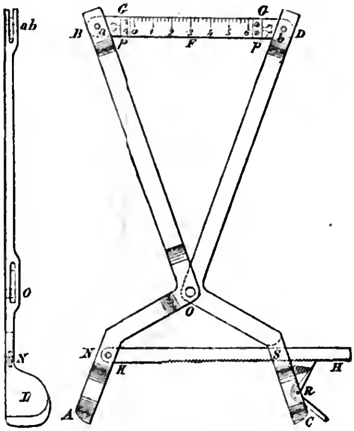
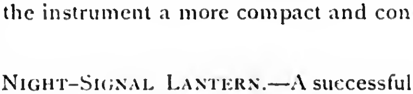


FIG. 1.

for the interpolation of other level curves or soundings, without using dividers or scale. The mean feature of such device is a rubber-band graduated scale, which can be stretched to more than double its ordinary length. This stretching the inventor accomplishes by securing the extremities of the rubber

Fig. 2.



scale to a pair of double tongs provided with ratchet, as shown in *Fig. 1;* but the simplest way of accomplishing this, we think, would be to secure such scale to a slide provided with a set screw, as shown in *Fig. 2,* which evidently would give the instrument a more compact and convenient form.

L. D'A.

THE OATMAN NIGHT-SIGNAL LANTERN.—A successful test of the Oatman night-signal lantern was made recently by officers of the army and navy. The common torch, lighted with lard oil or turpentine, has heretofore been used for carrying messages at night between far-off stations, on board ship as well as on shore, but the system has proved untrustworthy. The Oatman lantern is so arranged by a simple mechanical device that flashes of light can be shown as desired. These flashes correspond with the dash and the dot in the electric telegraph system—a long flash corresponding with the dash.

and a short flash with the dot. The lantern is not more than 18 inches high, and 8 inches square. A small lamp with the flame in the focus of a parabolic reflector furnishes the light. Fans close before the flame, by means of which the flashes are regulated, according to the Morse system of telegraphy. The flame is rendered steady by means of a forced draught. The longest distance signalled has been between Fort Myer and Sugar Loaf Mountain, Va., about thirty-five miles; signals have been exchanged between the reservoir in Brooklyn and Sandy Hook, about twenty miles apart.

Signals have been exchanged also between Ensign H. A. Bispham, U. S. N., Fleet Signal Officer of the North Atlantic Station, from Litchfield Castle, Prospect Park, Brooklyn, and Mr. Oatman, on Jersey City Heights, and Lieut. John Adams, at Fort Hamilton.

The instrument was in splendid working order, and Mr. Bispham spoke in the highest terms of the great utility of the invention.—*N. Y. World.*

ELIZABETH THOMPSON SCIENCE FUND.—This fund, which has been established by Mrs. Elizabeth Thompson, of Stamford, Conn., "for the advancement and prosecution of scientific research in its broadest sense," now amounts to $25,000. As accumulated income is again available, the trustees desire to receive applications for appropriations in aid of scientific work. This endowment is not for the benefit of any one department of science, but it is the intention of the trustees to give the preference to those investigations *which cannot otherwise be provided for*, which have for their object the advancement of human knowledge or the benefit of mankind in general, rather than to researches directed to the solution of questions of merely local importance.

Applications for assistance from this fund should be accompanied by a full statement of the nature of the investigation, of the conditions under which it is to be prosecuted, and of the manner in which the appropriation asked for is to be expended. The application should be forwarded to the Secretary of the Board of Trustees, Dr. C. S. Minot, Harvard Medical School, Boston, Mass., U. S. A.

The following grants have been made:

(1.) $200, to the New England Meteorological Society for the investigation of cyclonic movements in New England.

(2.) $150, to Samuel Rideal, Esq., of University College, London, Eng., for investigations on the absorption of heat by odorous gases.

(3.) $75, to H. M. Howe, Esq., of Boston, Mass., for the investigation of fusible slags of copper and lead smelting.

(4.) $500, to Prof. J. Rosenthal, of Erlangen, Germany, for investigations on animal heat in health and disease.

(5.) $50, to Joseph Jastrow, Esq., of the Johns Hopkins University, Baltimore, Md., for investigations on the laws of psycho-physics.

(Signed)

H. P. BOWDITCH, *President.* FRANCIS A. WALKER.
WM. MINOT, JR., *Treasurer.* EDW. C. PICKERING.
CHARLES SEDGWICK MINOT, *Secretary.*